AD ________________

GRANT NUMBER DAMD17-94-J-4485

TITLE: Virtual Environment for Surgical Room of the Future

PRINCIPAL INVESTIGATOR: Dr. Kenneth Kaplan

CONTRACTING ORGANIZATION: Massachusetts Institute of Technology
Cambridge, Massachusetts 02139-4307

REPORT DATE: October 1995

TYPE OF REPORT: Final

PREPARED FOR: U.S. Army Medical Research and Materiel Command
Fort Detrick, Maryland 21702-5012

DISTRIBUTION STATEMENT: Approved for public release;
distribution unlimited

The views, opinions and/or findings contained in this report are those of the author(s) and should not be construed as an official Department of the Army position, policy or decision unless so designated by other documentation.

DISCLAIMER NOTICE

THIS DOCUMENT IS BEST QUALITY AVAILABLE. THE COPY FURNISHED TO DTIC CONTAINED A SIGNIFICANT NUMBER OF PAGES WHICH DO NOT REPRODUCE LEGIBLY.

REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1. AGENCY USE ONLY *(Leave blank)*	2. REPORT DATE	3. REPORT TYPE AND DATES COVERED
	October 1995	Final (16 Sep 94 - 15 Sep 95)

4. TITLE AND SUBTITLE
Virtual Environment for Surgical Room of the Future

5. FUNDING NUMBERS
DAMD17-94-J-4485

6. AUTHOR(S)
Dr. Kenneth Kaplan

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
Massachusetts Institute of Technology
Cambridge, Massachusetts 02139-4307

8. PERFORMING ORGANIZATION REPORT NUMBER

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)
U.S. Army Medical Research and Materiel Command
Fort Detrick, Maryland 21702-5012

10. SPONSORING/MONITORING AGENCY REPORT NUMBER

11. SUPPLEMENTARY NOTES

12a. DISTRIBUTION / AVAILABILITY STATEMENT
Approved for public release; distribution unlimited

12b. DISTRIBUTION CODE

13. ABSTRACT *(Maximum 200* The goal of this project was to create a unique multimodal virtual design environment tha tcan be used to reconceptualize current surgical environments and to anticipate changes in these environments necessitated by ongoing technological progress in surgical treatment and training. The project will serve the dual needs of both civilian and military health care by developing a design for an operating room of the future, as conceived within the contextan adaptive vision of the hospital of the furture Innovate new medical technologies currently being developed to meet military needs will be incorporated in these designs. Ultimately, a prototype of a new surgical room design is proposed to be placed at the Massachusetts General Hospital for demonstration, testing, and evaluation.

14. SUBJECT TERMS Virtual Design Environment, Surgical Room, Medical Technologies

15. NUMBER OF PAGES
67

16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT
Unclassified	Unclassified	Unclassified	Unlimited

NSN 7540-01-280-5500

Standard Form 298 (Rev. 2-89)
Prescribed by ANSI Std. Z39-18

FOREWORD

Opinions, interpretations, conclusions and recommendations are those of the author and are not necessarily endorsed by the U.S. Army.

____ Where copyrighted material is quoted, permission has been obtained to use such material.

____ Where material from documents designated for limited distribution is quoted, permission has been obtained to use the material.

_✓_ Citations of commercial organizations and trade names in this report do not constitute an official Department of Army endorsement or approval of the products or services of these organizations.

____ In conducting research using animals, the investigator(s) adhered to the "Guide for the Care and Use of Laboratory Animals," prepared by the Committee on Care and use of Laboratory Animals of the Institute of Laboratory Resources, national Research Council (NIH Publication No. 86-23, Revised 1985).

____ For the protection of human subjects, the investigator(s) adhered to policies of applicable Federal Law 45 CFR 46.

____ In conducting research utilizing recombinant DNA technology, the investigator(s) adhered to current guidelines promulgated by the National Institutes of Health.

____ In the conduct of research utilizing recombinant DNA, the investigator(s) adhered to the NIH Guidelines for Research Involving Recombinant DNA Molecules.

____ In the conduct of research involving hazardous organisms, the investigator(s) adhered to the CDC-NIH Guide for Biosafety in Microbiological and Biomedical Laboratories.

Kenneth L. Kaplan — 16 Jan 97

PI - Signature — Date

Table of Contents

The Final Report for Virtual Environment for Surgical Room of the Future

(aka Virtual Prototyping of the Future)

Introduction:

Rapid technological innovation in the last decade has provided society with a glimpse of the profound importance that these technologies will have on the future of our habitable environment. One group that vividly recognizes this advancement -- a collaborative team of scientists, designers, and engineers, and surgeons from Harvard University, the Massachusetts Institute of Technology, and the Massachusetts General Hospital -- have begun to explore to the dimensions this technology in the design and development of a surgical room. The goal of the project was to create a unique multimodal virtual design environment that can be used to reconceptualize current surgical environments and to anticipate changes in these environments necessitated by ongoing technological progress in surgical treatment and training. The project will serve the dual needs of both civilian and military health care by developing a design for an operating room of the future, as conceived within the context of an adaptive vision of the hospital of the future. Innovative new medical technologies currently being developed to meet military needs will be incorporated in these designs. Ultimately, a prototype of a new surgical room design is proposed to be placed at the Massachusetts General Hospital (MGH) for demonstration, testing, and evaluation.

The Problem

Surgical procedures of great complexity are currently performed in operating environments that have not changed substantially in many years except for constant retrofitting to accommodate ever-changing medical technologies.

These actual and anticipated advances in modern surgical treatment methods have long outpaced developments in the architectural design of the environments which house them. Not only are these operating environments incapable of adapting to changing surgical needs, but their intrinsic architectural qualities are also insufficient. One MGH surgeon

defines the contemporary operating room as "a fairly sterile cold box in which medical equipment is positioned around the patient and medical practitioners...there is a lack of space...multiple cables prevent free circulation of personnel within the room creating hazards both electrical and physical...and communication is difficult".

There is an urgent need for improvements in operating room facilities. Equally important, however, are issues surrounding the role and functioning of an operating room within the context of a hospital and even larger medical care contexts. Current developments in information technology, telemedicine, remote surgery devices, and other developments are already beginning to pose a challenge to the very nature of current attitudes towards what a hospital should be -- with consequent challenges towards associated physical designs for hospital facilities. Rapid and accurate assessment of design changes within this process of redefinition is one of the primary functions of design within a virtual environment.

Many of these innovative technologies are being developed through sponsorship of the Advanced Biomedical Technology Program to serve military needs. There is great potential dual-use value to many of these technologies. The proposed LSTAT unit, for example, can easily be envisioned as meeting both military and civilian needs; the MEDFAST vehicle could also potentially be applied to both situations. These same technologies could provide a much-needed stimulus for further developments in the civilian health care domain.

A fundamental difficulty in responding to the need for improved operating rooms and reconceived hospitals is the lack of powerful capabilities for designing these sophisticated environments. Architectural firms, even those involved in hospital design, still use traditional CAD design and drafting tools of limited value. It is, therefore, not surprising that current architectural involvement rarely goes beyond providing a shell into which equipment and devices are placed.

Project Description: Three Phases

The project proposed herein is for the *first phase* of a multiyear project. The first phase undertakes the basic research and definition of performance requirements that are needed in order to implement the overall project vision. Subsequent phases will both enhance and ultimately implement the vision.

Initially, design requirements will be developed for an innovative *virtual environment* that supports the creative act of design in its many dimensions. The goal is to provide a new technological environment for realizing the act of design which may ultimately help create a new paradigm for architectural practice. This project will, using the design of an advanced operating room as a working model, demonstrate design capabilities within this environment.

The immersive design environment envisioned will be multimodal and thus provide design capabilities that go far beyond those possessed by traditional architectural design firms involved in surgical room and/or hospital design. The virtual environment envisioned will immerse both designers and users within the design world to be created *during* the actual design process. The Virtual environment will include not only capabilities for modeling the visual world, but will also include audio and haptic interfaces, as well as their subsequent implementations. Rather than simply sitting in front of a computer screen as is current practice, the designer will actually be immersed in the design world in a multisensory way during the creative act itself; this unique design environment will be used to create a surgical room of the future.

Users in the immersed environment will be able to evaluate elements such as equipment placement, lighting, and acoustic environments which affect the quality and functionality of the space from individual perspectives. A certain uniqueness will arise from the intersection of architecture and the world of virtual environments: namely, a combination of experience with design, human factors, environmental systems, structures, and materials with the full potential of the world of virtual environment technology.

PHASE I

Development of the virtual design environment. A preliminary design for an operating room will be prepared to serve as an applications demonstration.

PHASE II

Design of a surgical room, incorporating further development of the Virtual environment .

PHASE III

Development of a room prototype at the Massachusetts General Hospital for demonstration, testing, and evaluation. The room will be capable of incorporating new developments in medical technology, as well as adapting to technologies of the future. The room will be wireless and will incorporate advanced system integration concepts. The full potential of smart materials and other innovative technologies will be explored.

Virtual Design Environments

The ultimate vision proposed herein of the Virtual Design Environment (VDE) is that of a design environment that reflects an ideal view of architecture and related design activities as endeavors that fully integrate all aspects of a human's experience within his or her environment. All interactions that occur within this environment as a design world are considered susceptible to improvement through creative design acts. This view necessarily demands that the Virtual Design Environment be a multimodal system. It must go beyond the current practically exclusive preoccupation with the visual world of most virtual reality systems to include full auditory and haptic capabilities with associated interfaces. Achieving this end will be a truly innovative development and contribution to virtual environment technology.

This vision of an encompassing architecture demands that the architectural approach to be adopted in using Virtual Design Environment technologies must supersede conventional practice in its definition of what constitutes the designed environment (traditionally limited to the room shell and basic environmental systems). In the proposed approach, the designed environment is conceived of as a complete and integrated continuum that includes not only larger hospital and room environments, but considers the immediate surgical setting (including devices such as telesurgery systems, anesthesiology workstations, the surgical table, etc.) as a critical part of the room architecture. This approach is founded on the obvious and reasonable premise that room qualities necessarily affect the design and placement of devices within the surgical setting and vice versa.

Ultimately, this vision suggests that the designed world of the operating room encompass a continuum from the environment of the room through medical treatment devices, and down to the level of the surgeon's visual, auditory, and haptic experience of the organ. This integration is the ultimate goal underlying the specific kind of Virtual Design Environment (VDE) technology herein proposed. On a practical level, it can be perhaps argued that the linkage to organ models and surgical simulations is not directly necessary to achieve good designs of the room and immediate surgical environment, but developing a capability for design and user interactions at *any* point along this continuum will give the Virtual Design Environment a power and usefulness that simply transcends debates of this type. Conceiving of the design problem in this way also ultimately allows the virtual models created as part of the architectural design to be useful for other purposes. For example, by designing the Virtual Design Environment so that it has capabilities for effectively interfacing with any of several good surgical simulation systems, or even having a surgical simulation system as part of the virtual environment created, a training system of unparalleled value could be created in which surgeons in training could operate on virtual organs via virtual surgery devices -- all within a virtual operating room.

The vision of the Virtual Design Environment as a multimodal system that can support design and user interactions at any point along a continuum of

changing relevant environments (room, devices, body) can usefully be brought to an even higher level of interest. Designers now cannot actually enter the world that they are designing except through their imaginations. The traditional design tools of drawings or models -- even sophisticated rendered and animated models in a computer-aided design environment -- still necessarily place the designer (and certainly the user-client) *outside* of the design world as an observer looking into it. Literally, the designer is usually looking at a computer screen, drawing, or model. The vision of the Virtual Design Environment proposed herein is that the architect or designer would enter into the design world being created during the actual act of creation -- all through virtual environment technologies. The design world would be created *while* the designer is immersed within it. This concept has the potential for forever altering paradigms about how design occurs.

Ultimately, the Virtual Design Environment (VDE) will be developed to support many of the implementation issues described in Section Four (e.g., structural analysis and design, design for manufacturing and assembly, parts inventory, etc.).

<u>Preliminary Surgical Room Design</u> (See Appendix 4)

A preliminary design for an operating room of the future would be developed as part of first phase activities as a demonstration of the capabilities of the Virtual Design Environment.

Immediate architectural goals of the project are threefold:

1. Improvement of the human factors environment for medical personnel and patients by reducing the hostile interface between patients, health care providers, and surgical spaces.

2. Improvement of surgical efficiency by simplifying complex technical barriers that exist between surgeons, medical equipment, supporting information, and control systems.

3. Improvement in room environments and components designed to facilitate procedural efficiency.

The project's architectural design activities will be pursued at several levels:

1. At the *level of the immediate surgical environment,* all critical components will be modeled, including telesurgery devices which will be operable in real time. As discussed in Section 1 (Innovative Claims), telesurgery and other devices are considered in this architectural design approach as integral parts of the comprehensive design model to be developed. Only by considering this integration can a truly effective and innovative operating environment of the future be designed. Human interactions with these and other medical technology devices are also considered as integral parts of larger architectural design activities which necessarily consider interactions of building occupants with their surrounding environments. Modeling at this level will also include the surgical table, monitoring and display devices, support tables, and specific instruments such as IV poles and localized controls. This comprehensive view of what actually constitutes the architectural design world provides specific requirements for the VDE. Ultimately, this comprehensive architectural world should be capable of being coupled with simulation modeling of organs, surgical treatments, etc.

2. At the *level of the room,* basic characteristics and components such as entries/exits, and windows, placement of surgical level equipment, storage facilities, and seating and viewing areas will be evaluated. Components to be studied in this context include: environmental apparatus such as climate and lighting controls and communication and procedural support systems.

3. At the *level of the building,* spatial configurations and entry/exit patterns in relation to standard hospital layouts will be analyzed in conjunction with evaluation of room level linkages to larger hospital environmental and medical support systems.

Within the virtual environment created, surgeons and other medical personnel will be able to enter into a proposed facility via virtual technologies. Users will walk around in the virtual space -- literally putting

themselves in front of a virtual operating table with a virtual patient on it. The user will be able to look at equipment locations, lighting environments, and a host of other things that affect the quality and functionality of the room from the viewpoint of the user.

In the subsequent Phase II of the project, human movement and circulation (traffic patterns) as well as more sophisticated use issues can be explored. As noted earlier, the project will ultimately explore the use of teleoperated systems, automatically controlled equipment, and other advanced technologies in the surgical room -- all dynamic systems that will be modeled and operated in real time within the virtual environment. For example, features such as operating tables and task-lighting devices may have movement capabilities that are not only more versatile than current designs, but responsive to control via biosensors, voice or other techniques. The activation and movement of devices of this type would be simulated within the virtual environment. A surgeon would thus be able to experience how a device such as special task-lighting would respond to requested changes, or how such a device would automatically adjust to changing conditions via sensory inputs. Design improvements would follow from the user feedback received.The room design to be developed will incorporate and apply exciting new technologies now under development for meeting military needs, but the design will not be restricted to them. The design constraints imposed by creating a surgical environment within a MEDFAST vehicle, for example, absolutely necessitate the kind of rigorous design thinking that will invaluably inform operating room environments in different contexts, adaptable to MASH units, military hospitals, and civilian hospitals.

Review of Project Activities and Conclusions:

Despite the importance and the great promise of the Virtual Design Environment for a Surgical Room of the Future there are a number of formidable technical problems that will inhibit progress of the project unless they are resolved. The issues can be divided into two categories, although many others can be conceived in a future study . The issues are very complex and are tied to the intricate definition of the architectural design process. However, most computer technology on the market today , hardware and software, are not compatible or flexible with the way architects actually design buildings. The predominance of computer technology was designed for word and numerical processing and has little adaptability for the kind of intuitive and multi-modal process that designers employ. A typical designer, across the course of a conceptual design phase of a project (about 6-8 weeks in duration will use a number of methods that include a vast range of materials like pencil, ink, clay, wood, metal, plastics of various sorts, natural materials, lighting, photography and many others that are literally impossible to catalog due to the unpredictability of the process. All the methods are attempts at "simulating"the actual building short of the possibility of spatial immersion in the actual future project. The fact of matter, today's computer technology can not simulate any of these methods, except rudimentary mechanical drawing, spatial modeling with ever-increasing color rendering capability. The primary issues of the building environment are many years away from being translated into computer simulation let alone 3-D immersive environments. The current crop of products that are marketed as "virtual reality" interfaces are primarily designed for game and entertainment applications and have so far, based on this study, have had little value in designing a sophisticated environment like a surgical room. Their capability is limited on a number of fronts and the following list is an attempt to document their short-comings. At this time, it would not be appropriate to list the actual products that were used as part of the project since the aim of the study was not a case of product testing. These comments are a generic reviewing of "cutting edge" technology as a basic research tool and are

restricted due to temporal and budgetary constraints of the project. The systems employed included all the components of hardware, software, displays and assorted peripherals that can be described as a "virtual reality interface":

1. Visual and graphic resolution is poor to fair in the affordable systems, whereas the better high-end systems due to costs and proprietary restraints are inaccessible to the profession or even the research community. None of the systems have resolution properties that could be adaptable to sophisticated building design. "Cartoon-like" qualities limit proper identification of environment factors like materials, lighting, texture, color and especially human form

2. No integration of material and physical properties with graphic software. Properties like air-flow, lighting, temperature gradients

3. Head-mounted displays not suited to design work; uncomfortable to wear for long periods and associated symptoms of disorientation like dizziness and nausea emerge after long-term application (more than an 1/2 hour)

4. Incompatibility of proprietary software across computer operating systems

5. Haptic and tactile interfaces, key to interacting with environmental factors prove to be unsatisfactory and at times non-functional

6. Interfaces for fine motor skills of design activity non-existent like drawing, sculpting and various shop skills

7. Immersion experience of 3-D "cave environments" highly disorienting due to poor physical cues for equilibrium and stabilization

8. The bandwidth demands of distributed simulation environments are beyond the capabilities of current OTS systems

9. All VE systems require a range of technical personnel to be available to user due to chronic and regular systems problems

10. Current CAD databases not easily or at all adaptable to VE systems

11. Extensive and expensive learning curve for designer user community

Conclusion:

Extensive research and development on virtual environment technology needs to occur before it can be applied as an architectural design tool. This is true at the level of the hardware and software. An extensive program needs to be developed that integrates the physical properties of built environments and their architectural representation. Some of this work is even at the basic science research level. For instance, the understanding of air flow dynamics and how to represent those forces visually and accurately during the design process is a basic need that, at this stage, fundamentally does not exist beyond a very rudimentary level. Room temperature ambience and how it effects the occupants in the room over the course of a day is not translated into any software package that is available let alone affordable. A full immersion technology platform into architectural space needs to be explored also at a basic science level. At this point immersion with current off the shelf technology is a very limited capability with problems in resolution, equilibrium, interactivity, motion control and ergonomic design. This is a major research project in itself and can not be simply handled with current off the shelf tools. A roadmap to develop this technology for design applications is required and should be the next phase before any work proceeds on the actual surgical room. This roadmap should include an industry-academic team that can outline more precisely what are the technologies available and how can they be integrated better, and then what would be the areas of future development. At this point this survey is vital and only exists in fragments throughout industry and the academic communities. A 6-month effort would be required

to put this survey together, then work can be resumed on the actual planning of the surgical room of the future.

Appendix 1: Program Team and Team Management

The project was managed by the Massachusetts Institute of Technology and will sub-contract to the Harvard University and the Massachusetts General Hospital. The teams will be headed by Principal Investigators: Dr. Kenneth Kaplan, MIT, Nathaniel Durlach and Ian Hunter, MIT, Professor Daniel Schodek, Harvard, and Drs. Steve Dawson and David Rattner from MGH.

The MIT/Harvard/MGH team consists of leading designers, engineers, scientists, inventors, surgeons, and others with a shared interest and expertise in new and emerging technologies in relation to the development of innovative Virtual design environments. A goal of this group is to advance the state of technologies used in the design process, while simultaneously inventing, testing, and developing the physical manifestations of the design in relation to the virtual environments they develop. The MIT/Harvard/MGH team will amalgamate many previously separated professions into a synthesized group through these advanced design tools.

Individuals in the MIT/Harvard/MGH team bring a unique combination of skills to the project, each contributing to the needs and specificity of the operating room. The combination of architects, engineers, scientists, and surgeons involved in the creation of virtual design environments is unprecedented and will allow for close collaboration on issues such as: the development, use and optimization of virtual environment technologies; programmatic and spatial analysis; advanced building technologies; structural engineering; materials engineering; rapid prototyping; and other fields. Building on these disciplines, members also have the capability to incorporate their work on teleoperations, micro-robotics and associated electro-optical-mechanical instrumentation into the hospital environments of the future.

Massachusetts Institute of Technology

Department of Architecture
Kenneth L. Kaplan
Emily M. Tucker

Massachusetts Institute of Technology
Department of Mechanical Engineering
Prof. Ian Hunter
Dr. Lynette Jones

Massachusetts Institute of Technology
Research Laboratory of Electronics
Prof. Walter A. Aviles
Nathaniel I. Durlach

University of Auckland, New Zealand
Department of Engineering Sciences
Prof. Peter Hunter

Harvard University
Graduate School of Design
Prof. Daniel L. Schodek
Shana Priwer

Massachusetts General Hospital
Dr. Steve Dawson
Dr. David Rattner

Foster Miller, Inc.
Anthony Aponick

Independent Consultants
Dr. Michael L. Burns, President, Science, Math & Engineering, Inc.
Wade Hokoda, Computer Graphics Specialist

Appendix 2: Problems in the OR: Twenty Issues for Examination

1. General Reporting of Medical Accidents and Device Failures

2. Accidents relating to the use of Lasers

3. Electrocautery Accidents

4. Speculations on Causes of Medical Accidents

5. Surgical Accidents/Medical Malpractice: Case Studies and Examples

6. Surgical Accidents/Medical Malpractice: Analysis, Statistical Data, and Commentary

7. Human Misuse of Medical Equipment: Deliberate and Accidental

8. Unsafe Medical Equipment and Machinery

9. Fires and Electrical Problems in the Operating Room

10. Pollutants and Environmental Hazards in the Surgical Room

11. Hospitals as Spreaders of Infection

12. Surgical Wound Infection

13. Operating Room Monitor Alarms

14. Deaths by Restraint

15. Monitoring

16. Serious Problems with Surgical Uniforms

17. Spread of disease doctor-to-patient, patient-to-doctor

18. Quality control issues

19. Standards

20. Miscellaneous

Appendix 3: VDE Specification (Off the Shelf)

• Hardware

ONYX Reality Engine, Silicon Graphics

-multi-channel option (output images to 4 different devices)

-64 megs of RAM

-16 megs of texture memory

-4 to 8 processors (the more the better)

-1 gigabyte hard disk

-SOFTWARE:

-"Developer's Option"

-"C" & "C++"

-"Performer" (low level graphics, improves performance of VR software)

Kubota Pacific Computer

-Santa Clara, CA

-based on DECs Alpha chip

• Software

WorldToolKit, Sense8

-1001 Bridgeway, Suite 447, Sausalito, CA 94965

-runs on both the SGI and the Kuboda

-simulation manager

-real-time rendering pipeline

-object manager

-lighting, animation sequences, input sensors, & graphic display devices

-ability to work with stereoscopic imaging and 3D sound (alliance with Crystal River Engineering, Intel, and StereoGraphics.

-access to functions that control low-level geometries for constructing virtual objects. Greater ability to control which tasks are executed and in what order.

-can construct virtual objects on-the-fly

-"C" based programming

-first released in 1991

-current version: 2.0

-price: $2,995

-support for HMD

-support for Polhemus Isotrack2 and Fastrack, and Ascention Bird joystick

-rendering card: Action Media 750, SPEA Fire

-scripting code: C++ function-based

-runtime license: $350-$1000 based on quantity

-user group: yes, administered by NASA Ames

-installed: licensed=1000+, developers=300+ (as of June 1993)

• Tracking

Polhemus "FASTRACK"

-One Hercules Drive, PO Box 560, Colchester, VT 05446

(802-655-3159 v, 802-655-1439 f)

(800-655-3159 x 234)

-six degree of freedom

-little latency

-uses digital signal processing (DSP) to accelerate tracking to 4ms

-update rate of 120 Hz

-operational range of 10 feet

-large company, more likely to donate equipment

-magnetic position sensor

-latency and eddy currents a problem with magnetic trackers

Ascention Technology "Flock of Birds"

-Burlington, VT

-magnetic position sensor

-latency and eddy currents a problem with magnetic trackers

• Head-Mounted Displays

BOOM3C (Binocular Omni-Oriented Monitor), Fakespace

- 4085 Campbell Ave., Menlo Park, CA 94025
- $95K
- mechanical system
- 1260 x 980 resolution
- full color
- two monochrome CRT displays with synchronized Tektronix color filters
- no lag or tracking delay

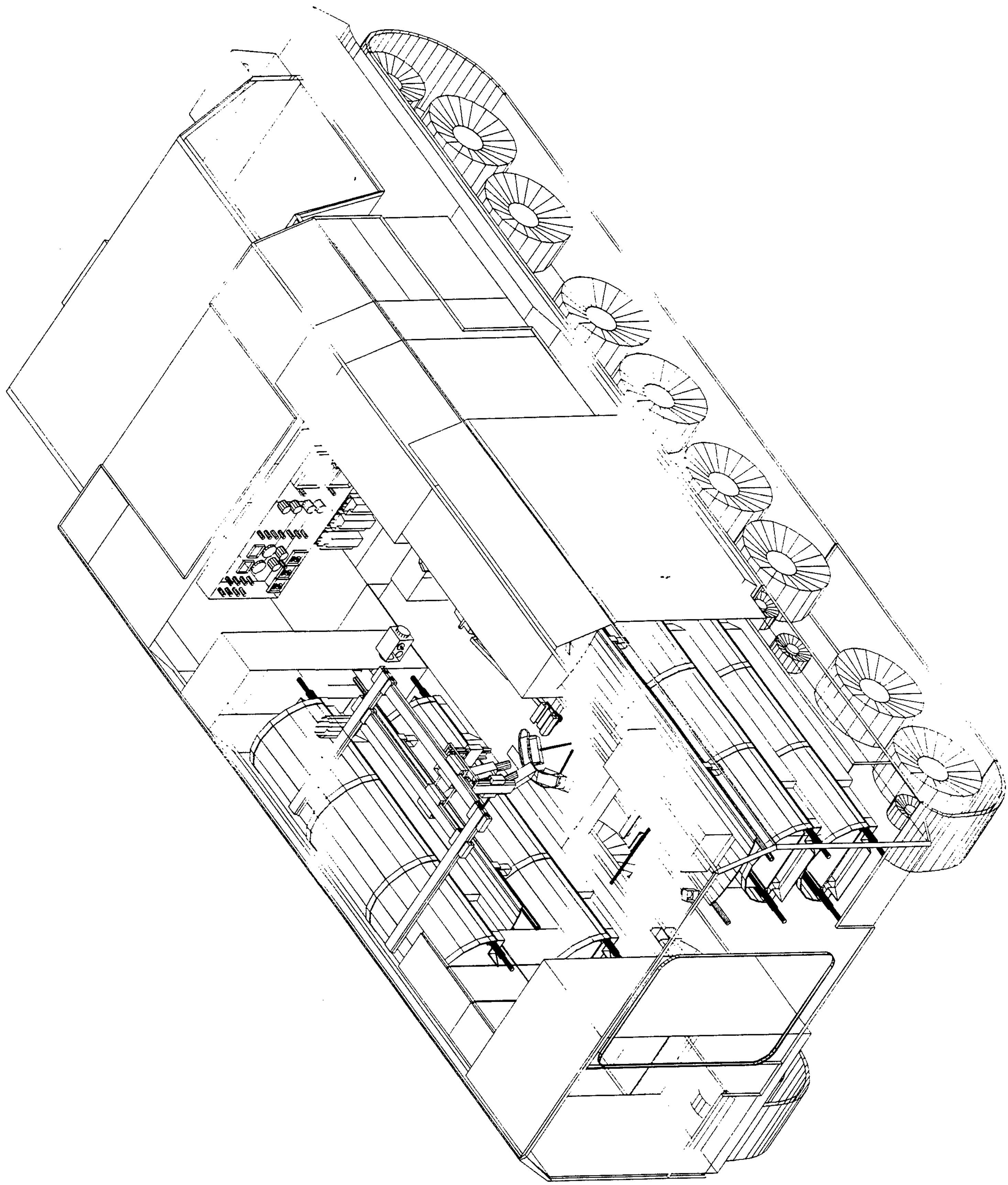
HMSI (Head Mounted Sensory Interface), RPI Advanced Technology Group

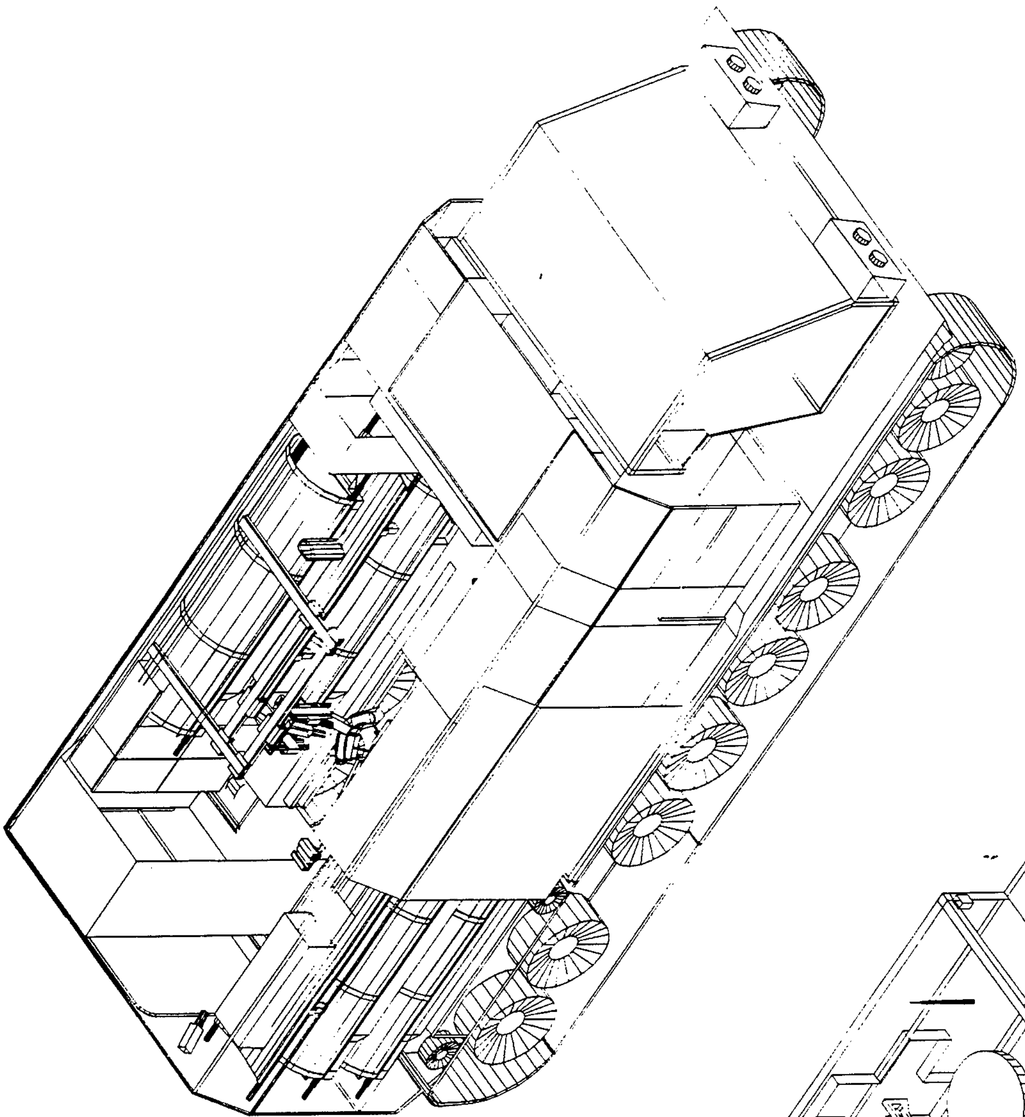
- PO Box 14607, San Francisco, CA 94114
- $15K
- 3 1/2 ounces (thick sunglasses)
- 450 x 220 res. (640 x 480 resolution quoted in CGW good enough for medical simulation)
- Field of View 65 to 110 degrees (blurring at 110 degrees)
- real world peripheral vision without eyecups
- Duane knows president, could get us beta of high-res version
- will soon be wireless (according to Duane)

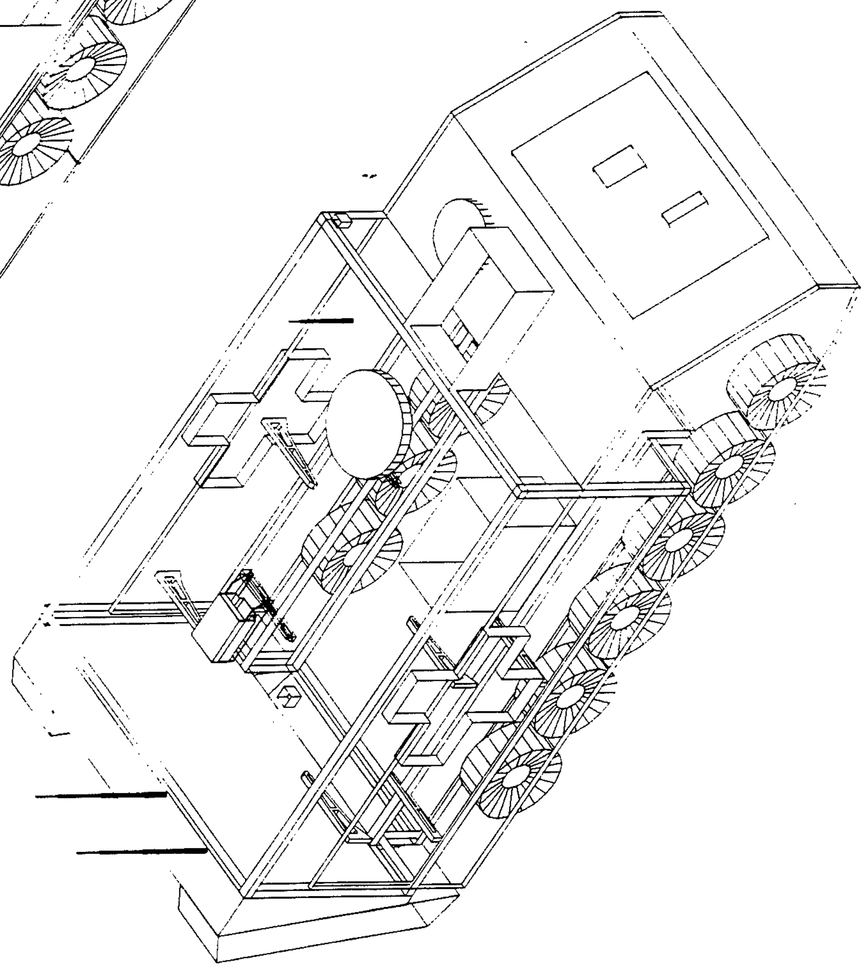
VIM (Vision Immersion Module), Kaiser Electro-Optics

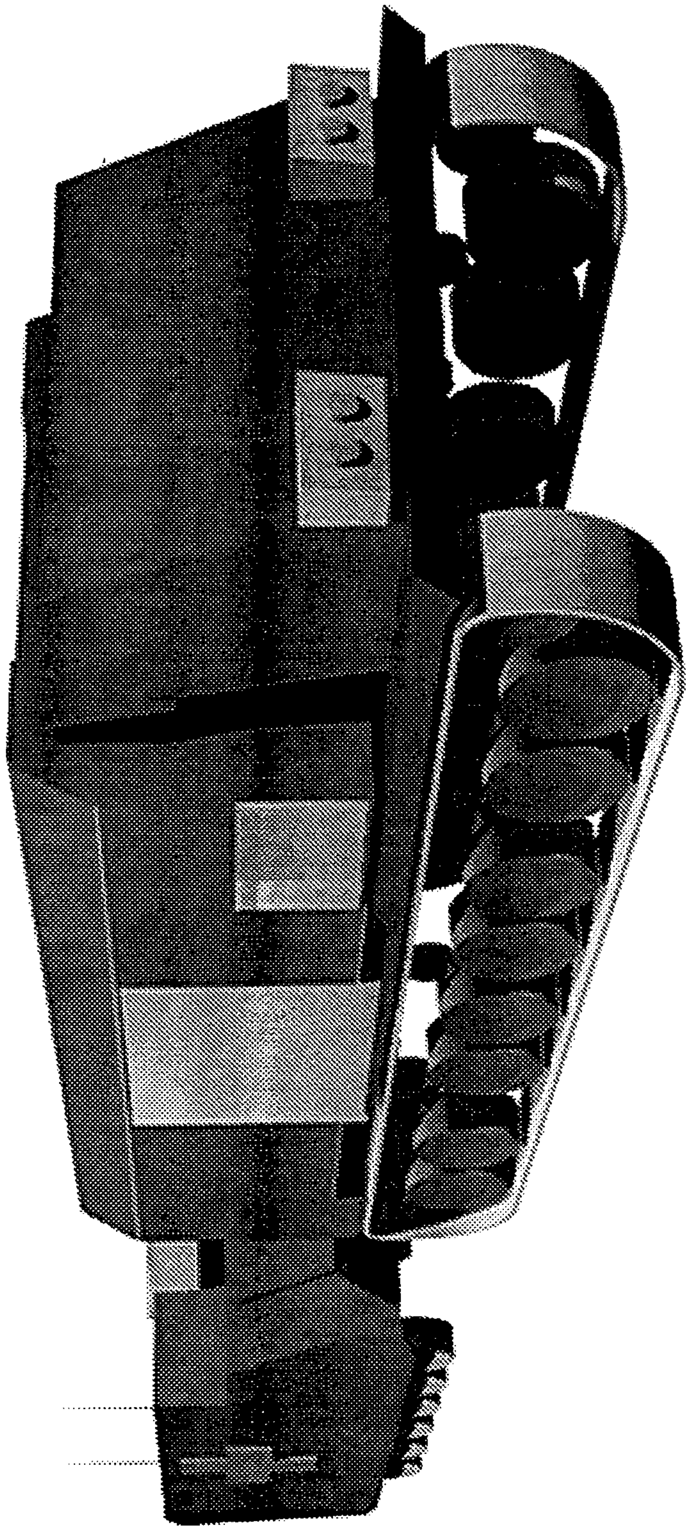
- 2752 Loker Ave. W., Carlsbad, CA 92008
- $15K
- visor-like display unit
- 4.3 lbs
- F.o.V. 30 deg. verticle, 100 deg. horizontal
- good resolution
- ability to tile the viewed image 2, 3, or 4 times across the viewing field (multiple viewports)
- big company, more likely to donate machinery

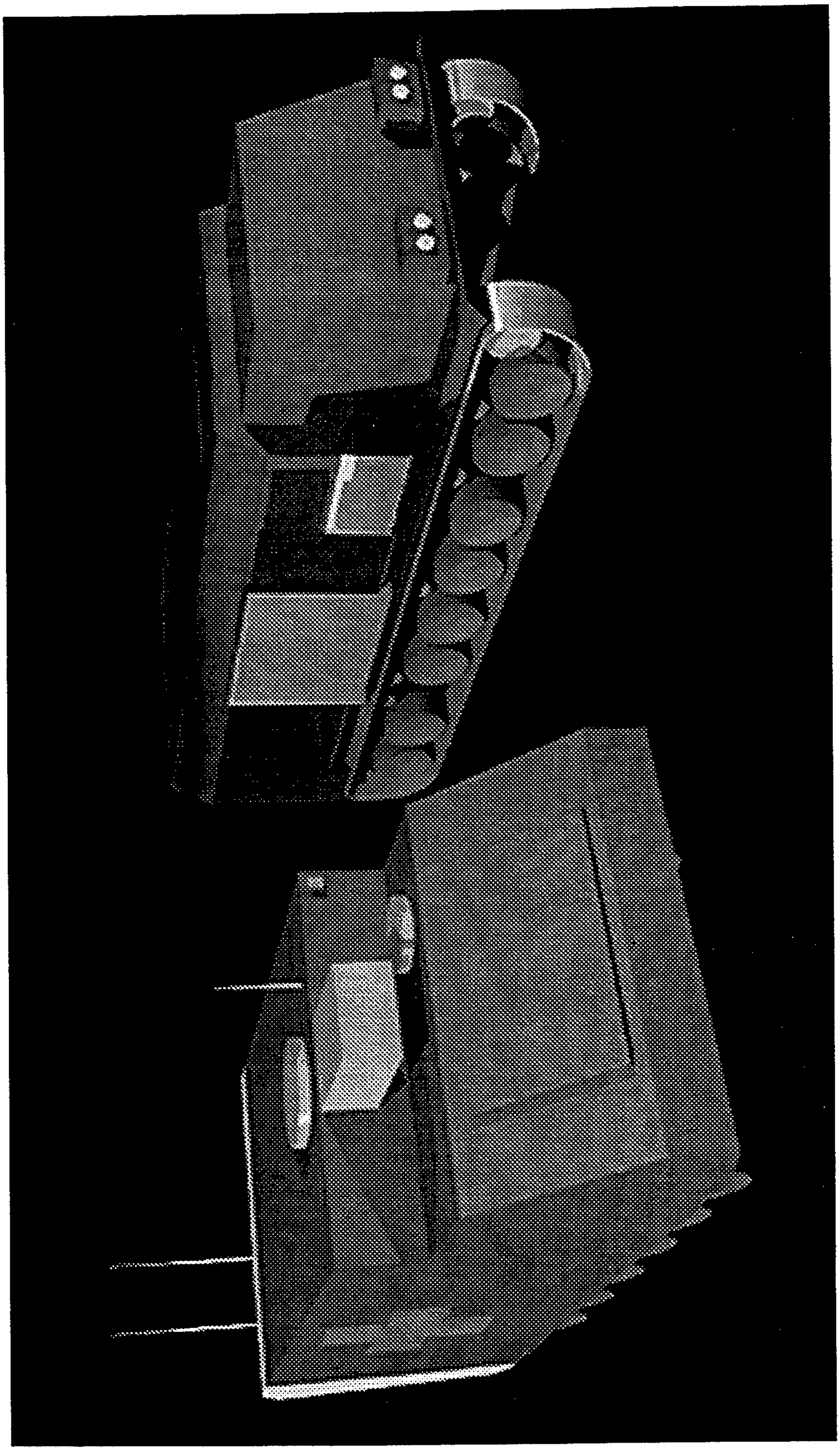
Appendix 4: Interoperability Studies of Current Health Care Delivery Systems

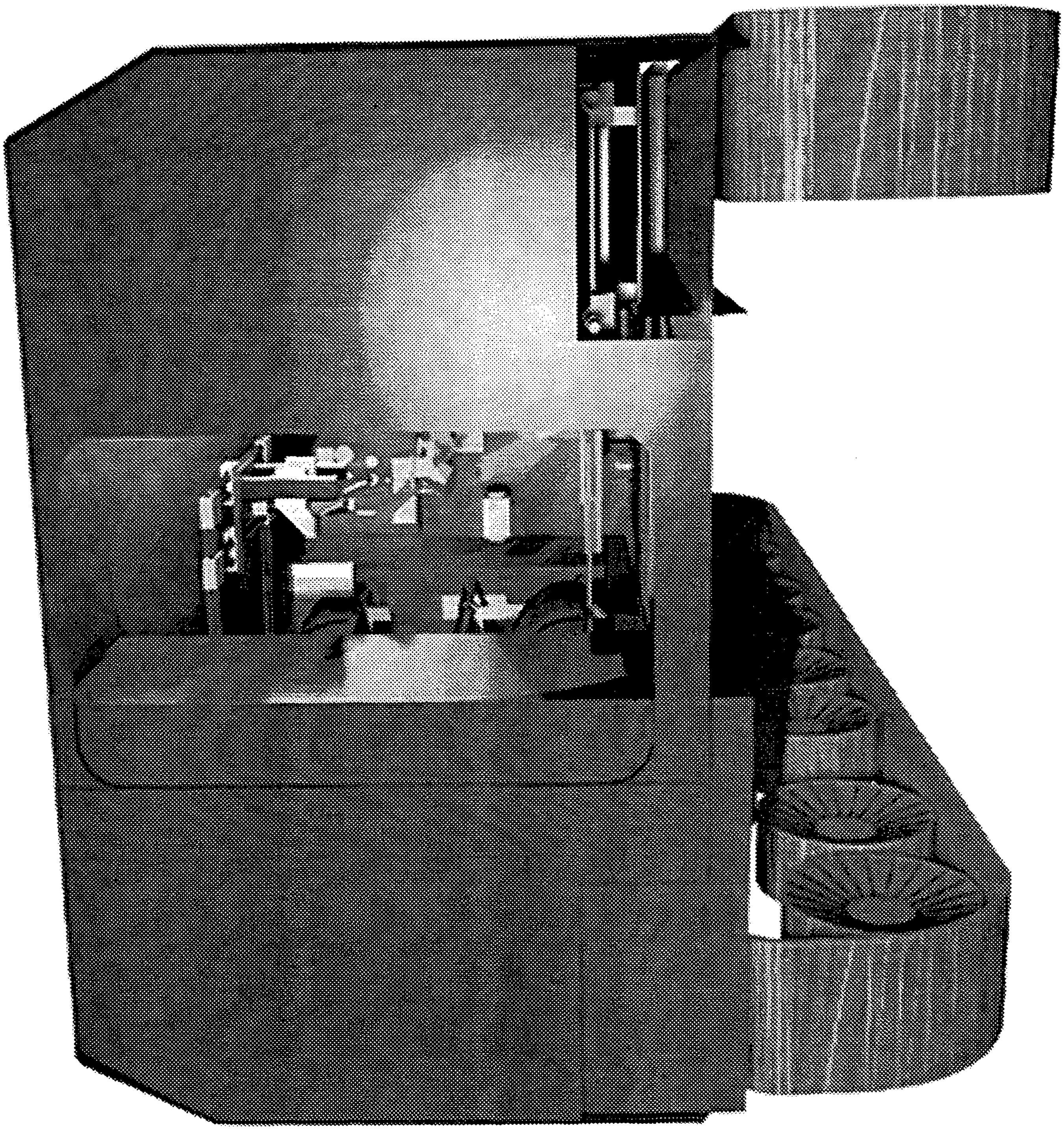


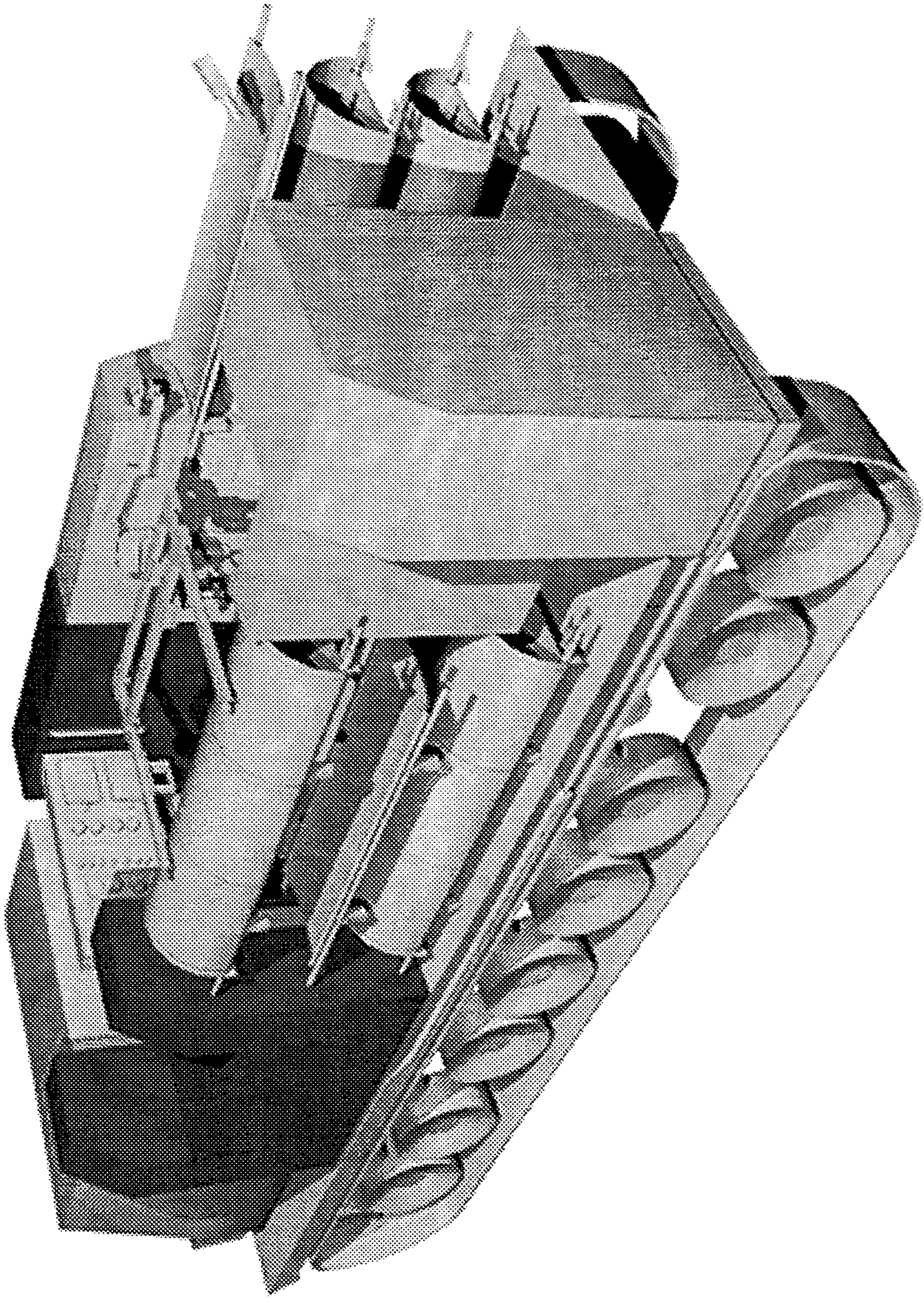


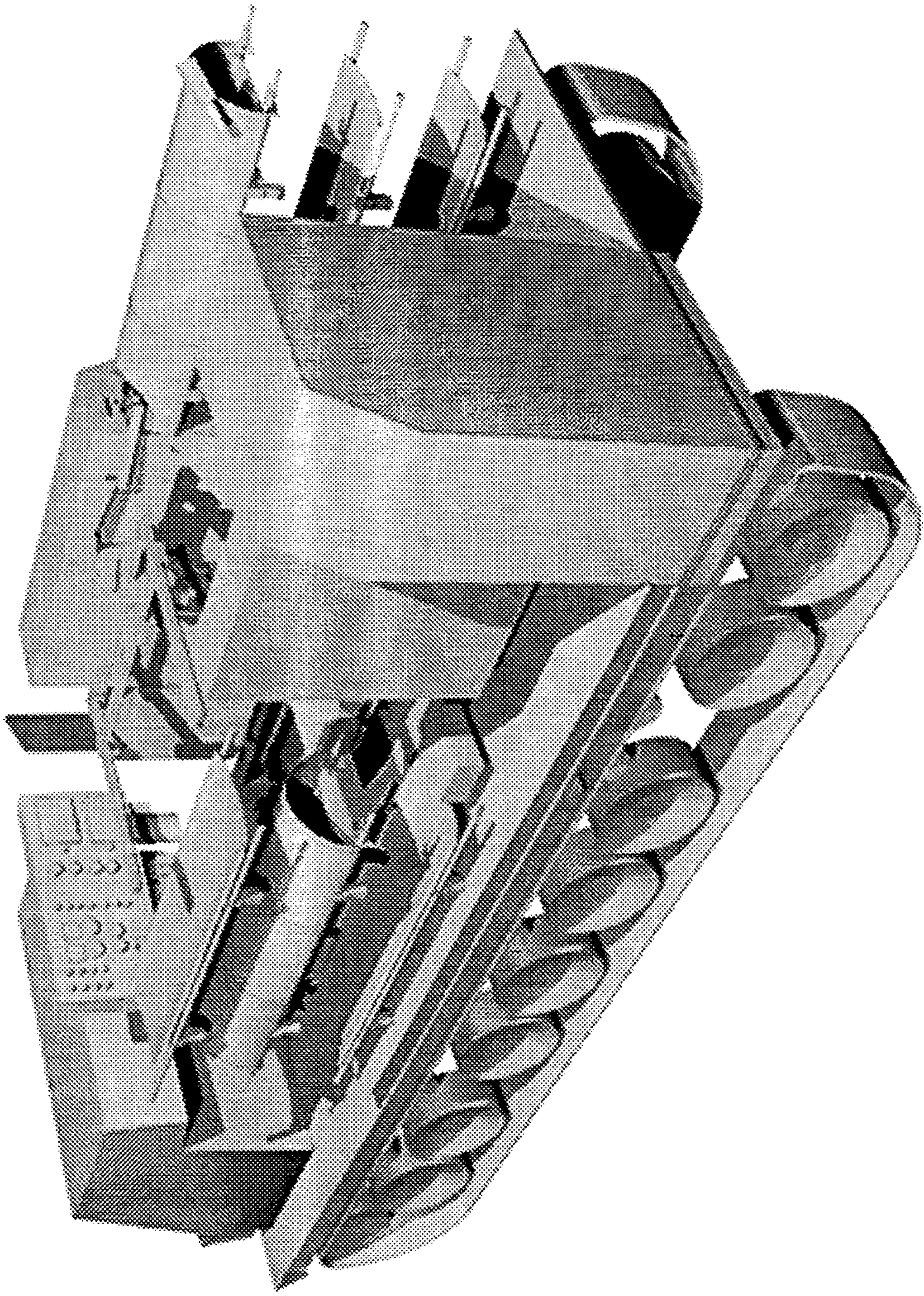


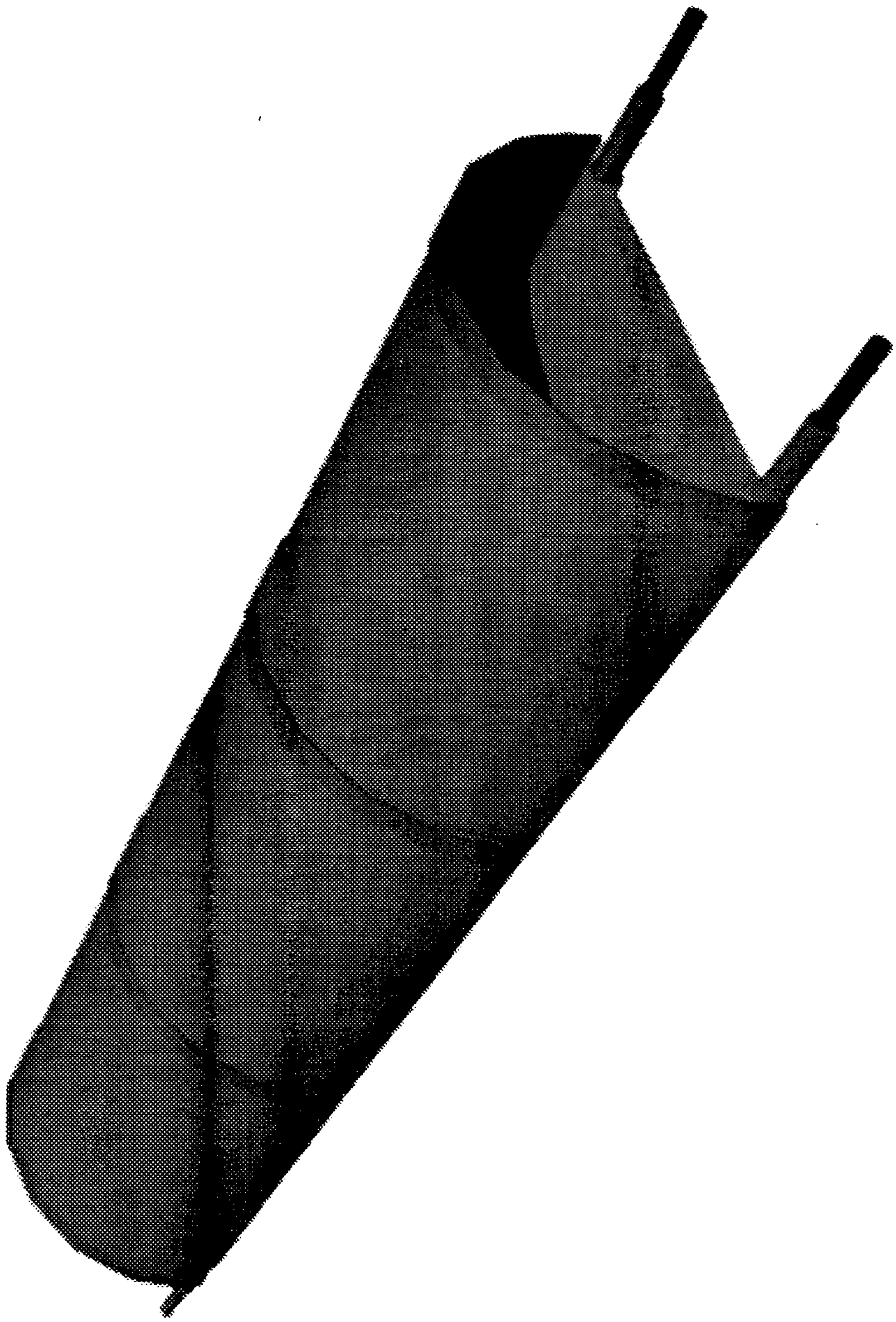


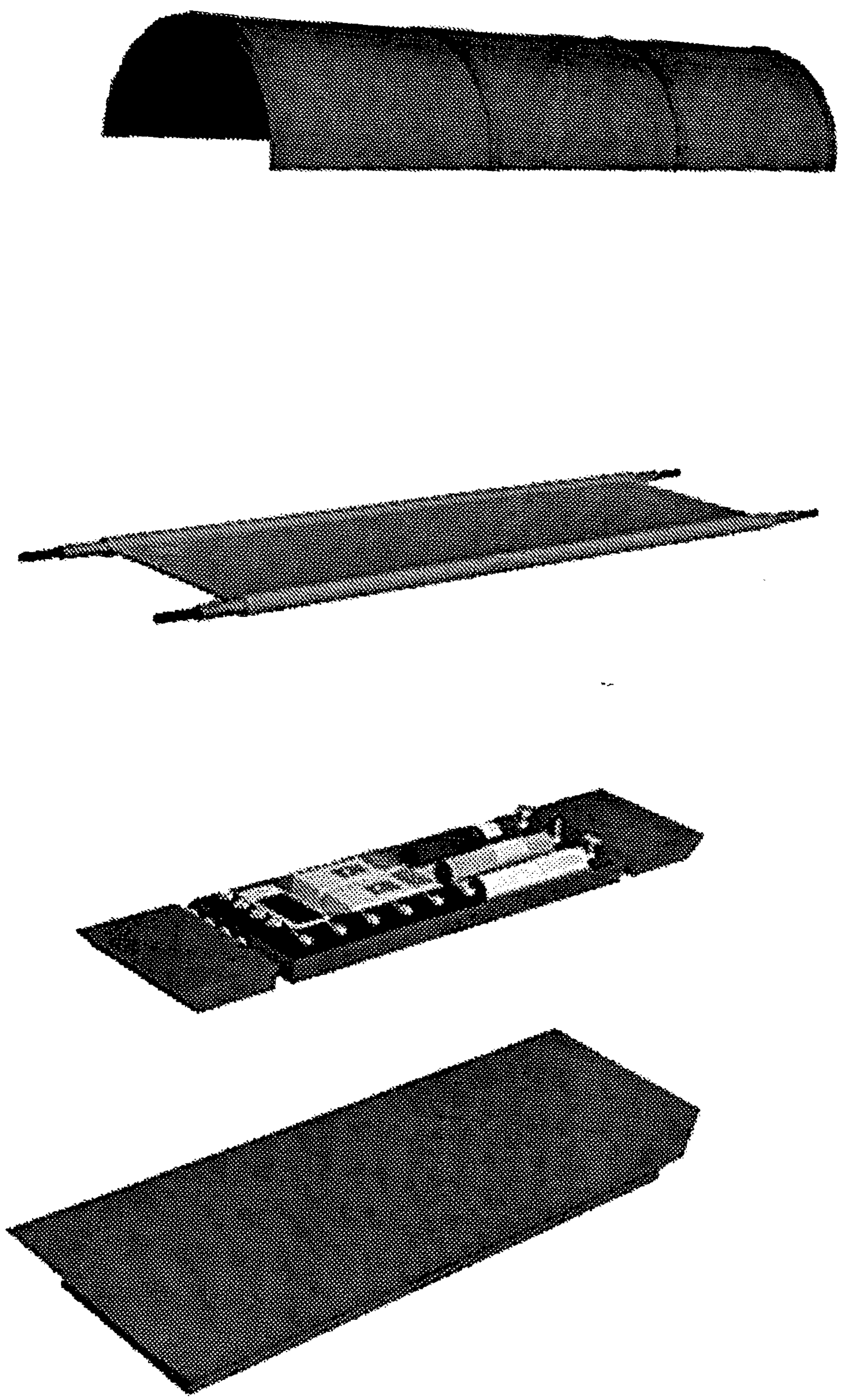


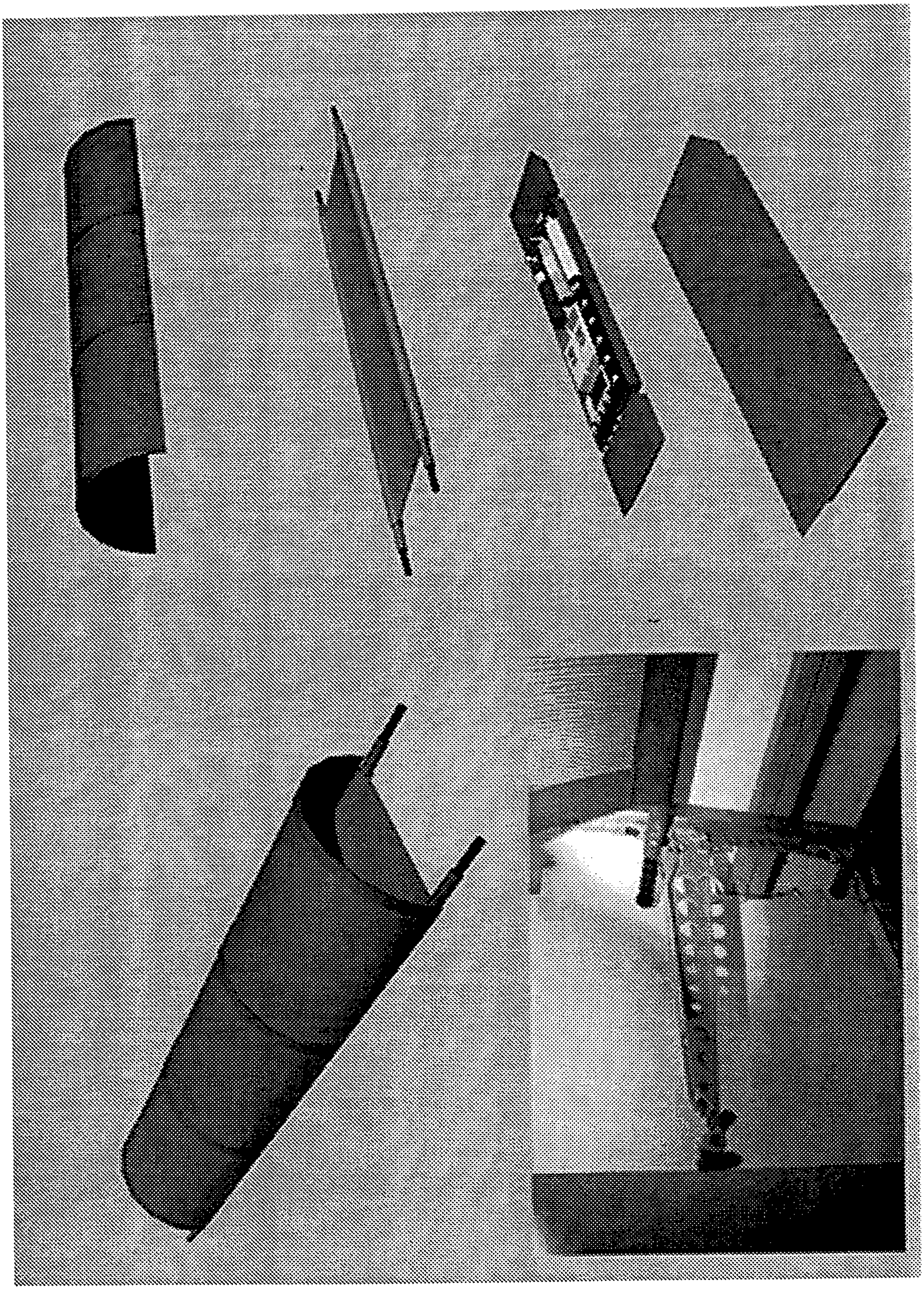


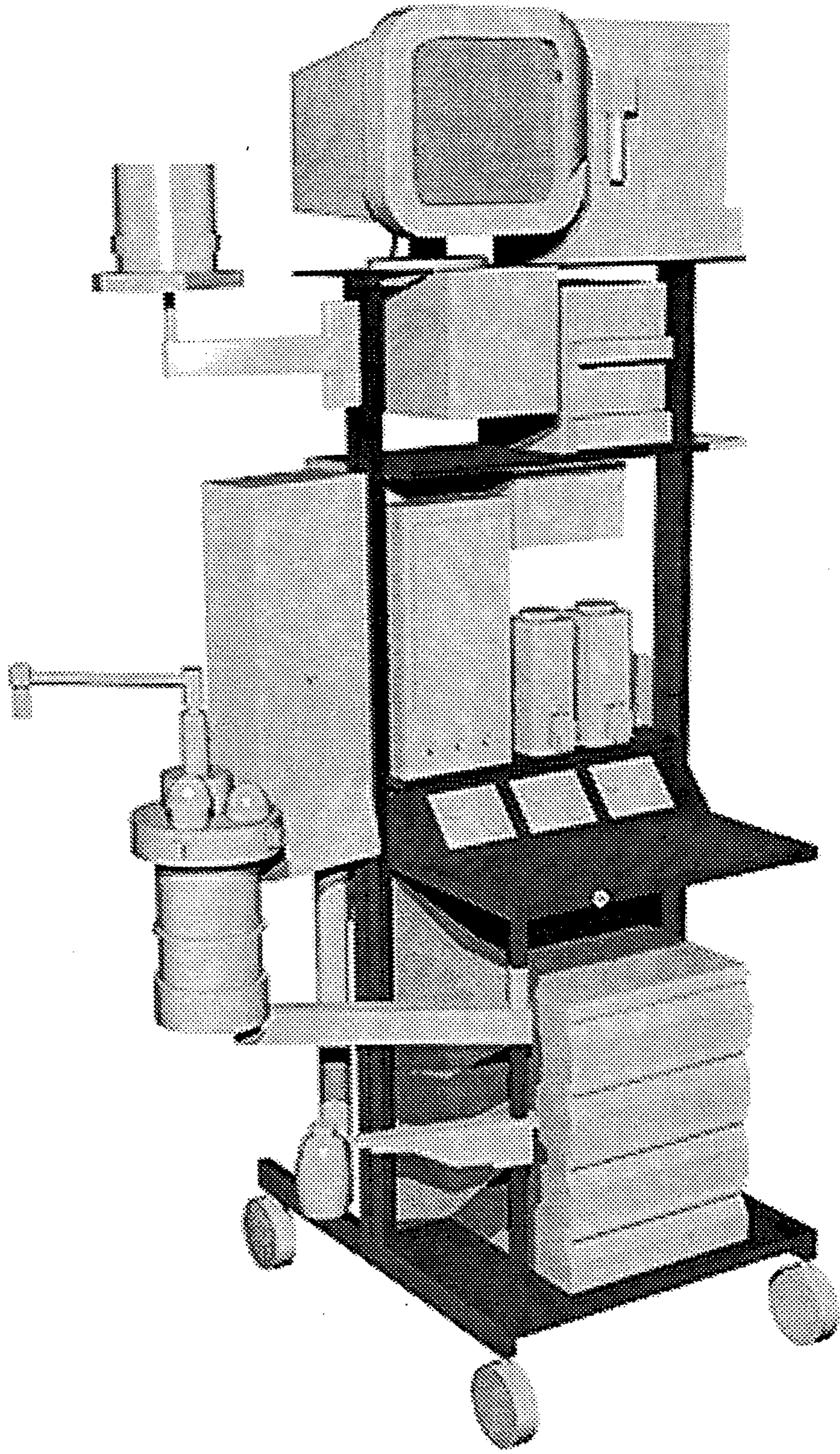


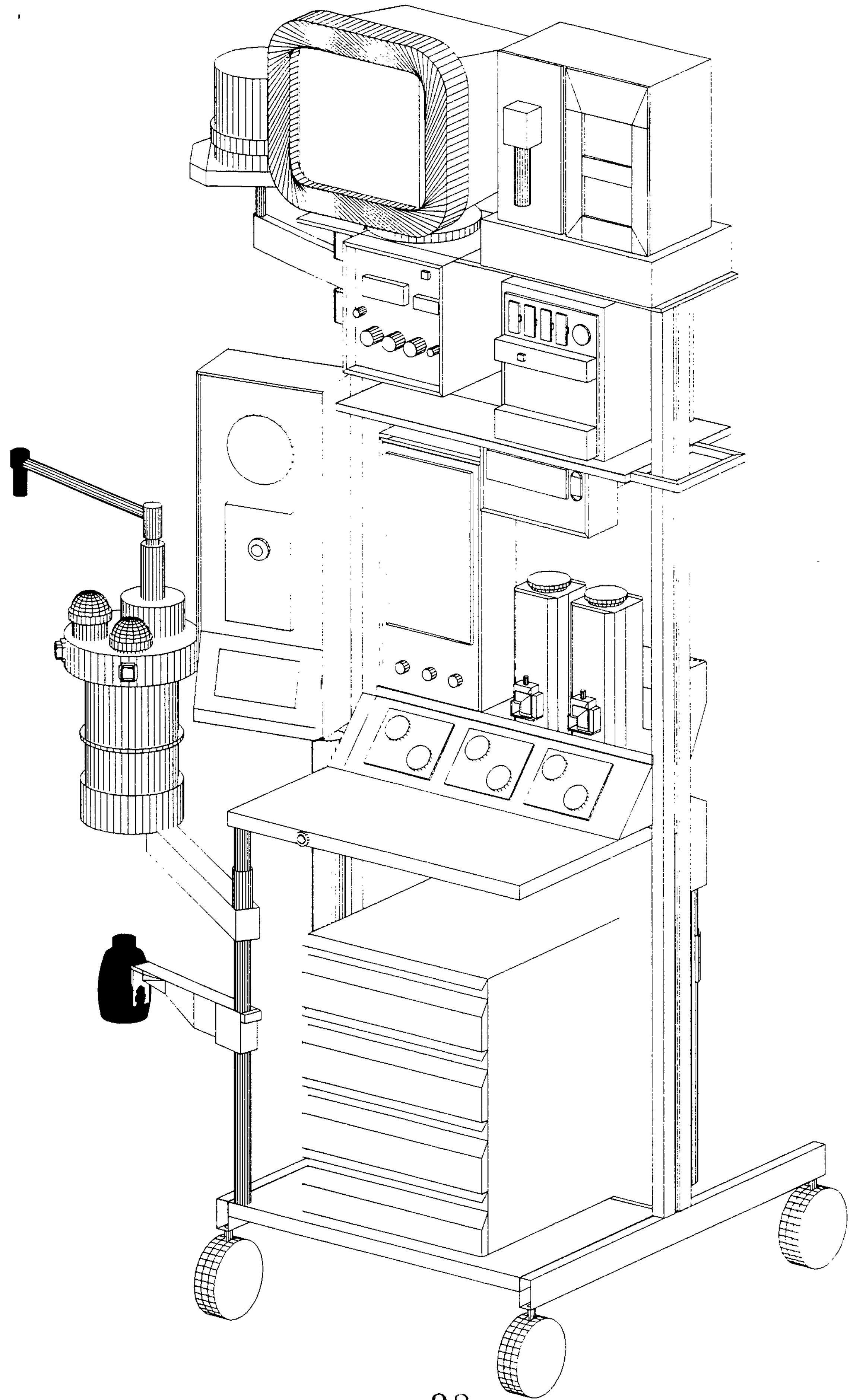


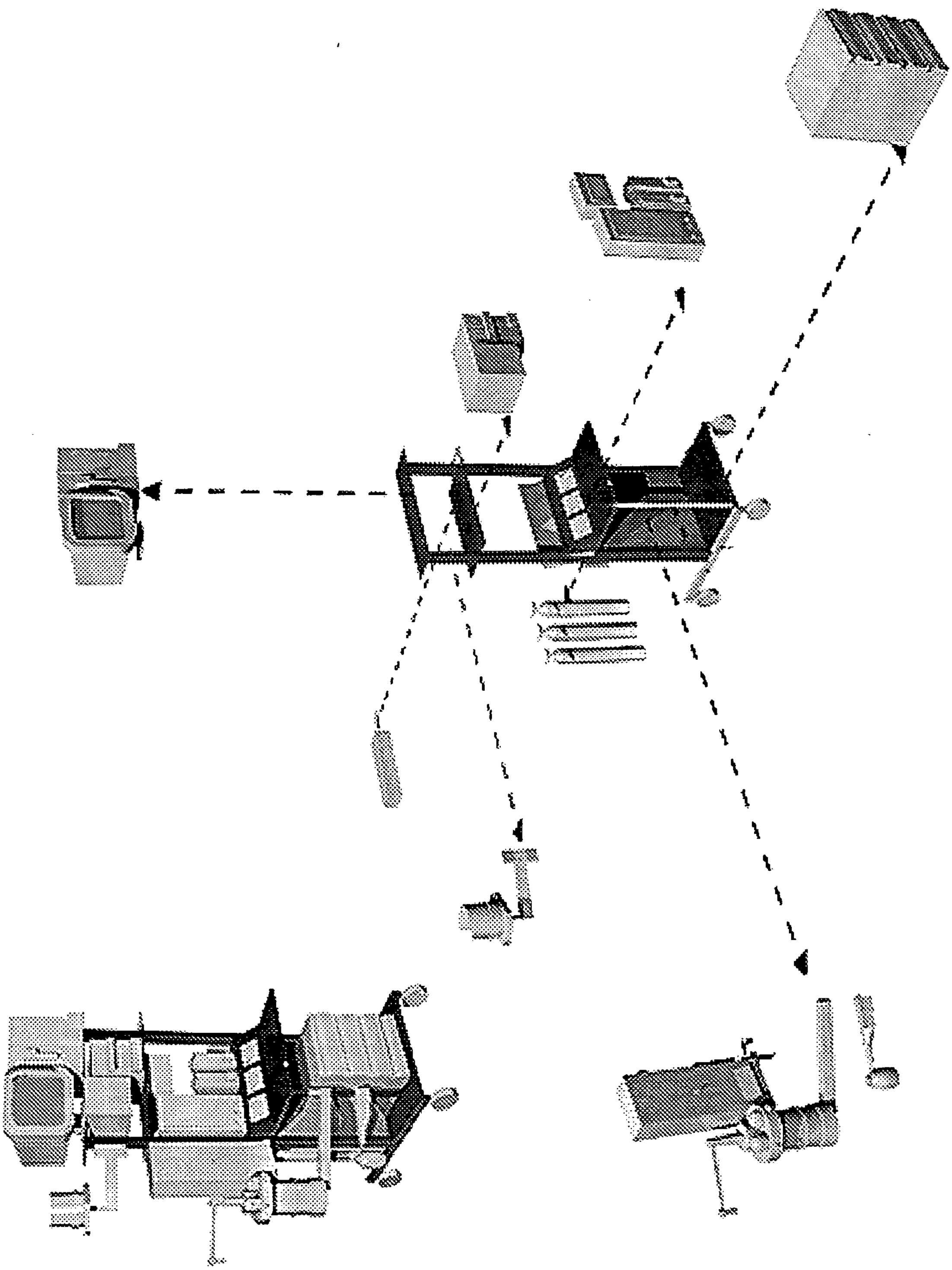


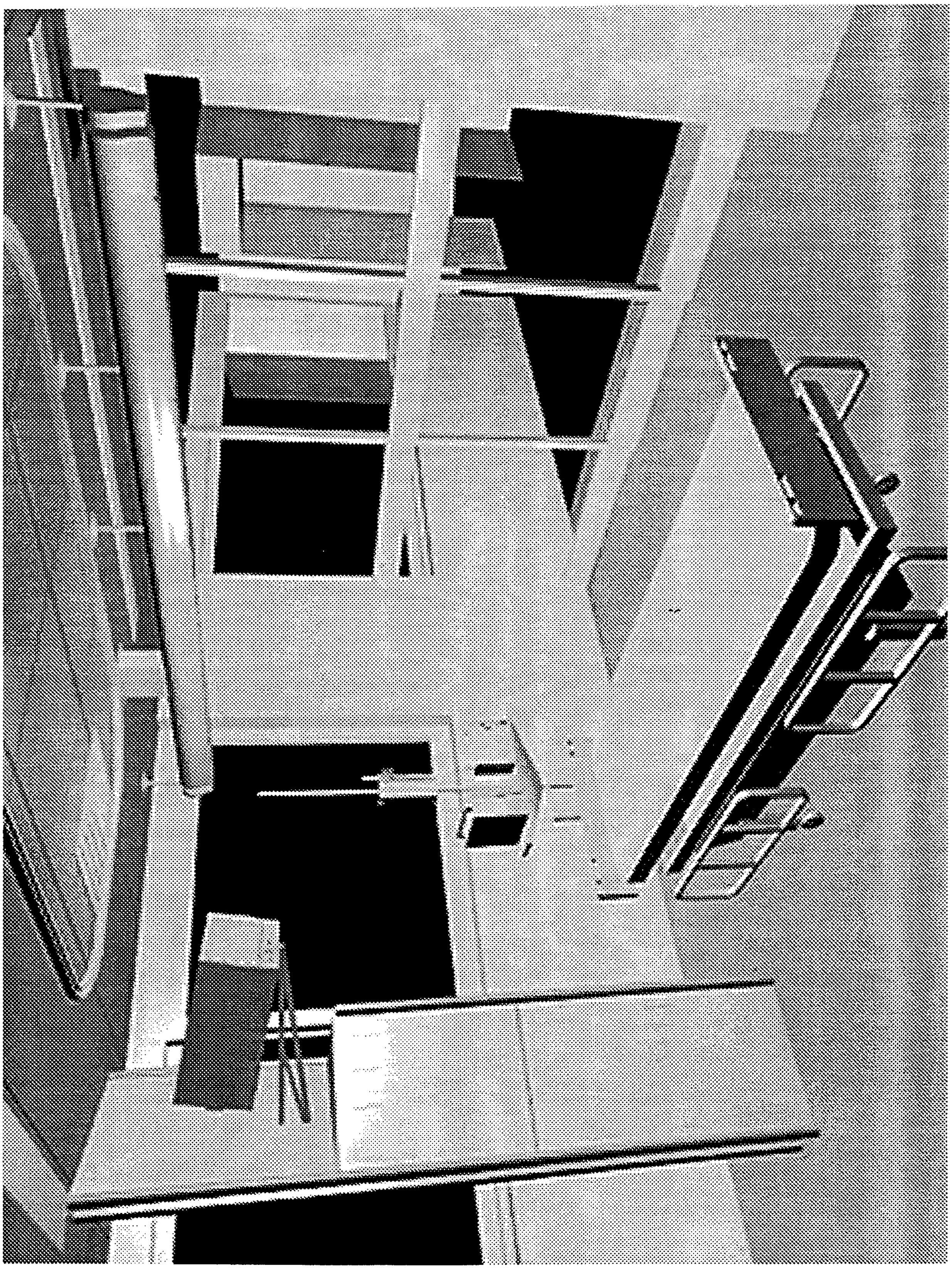


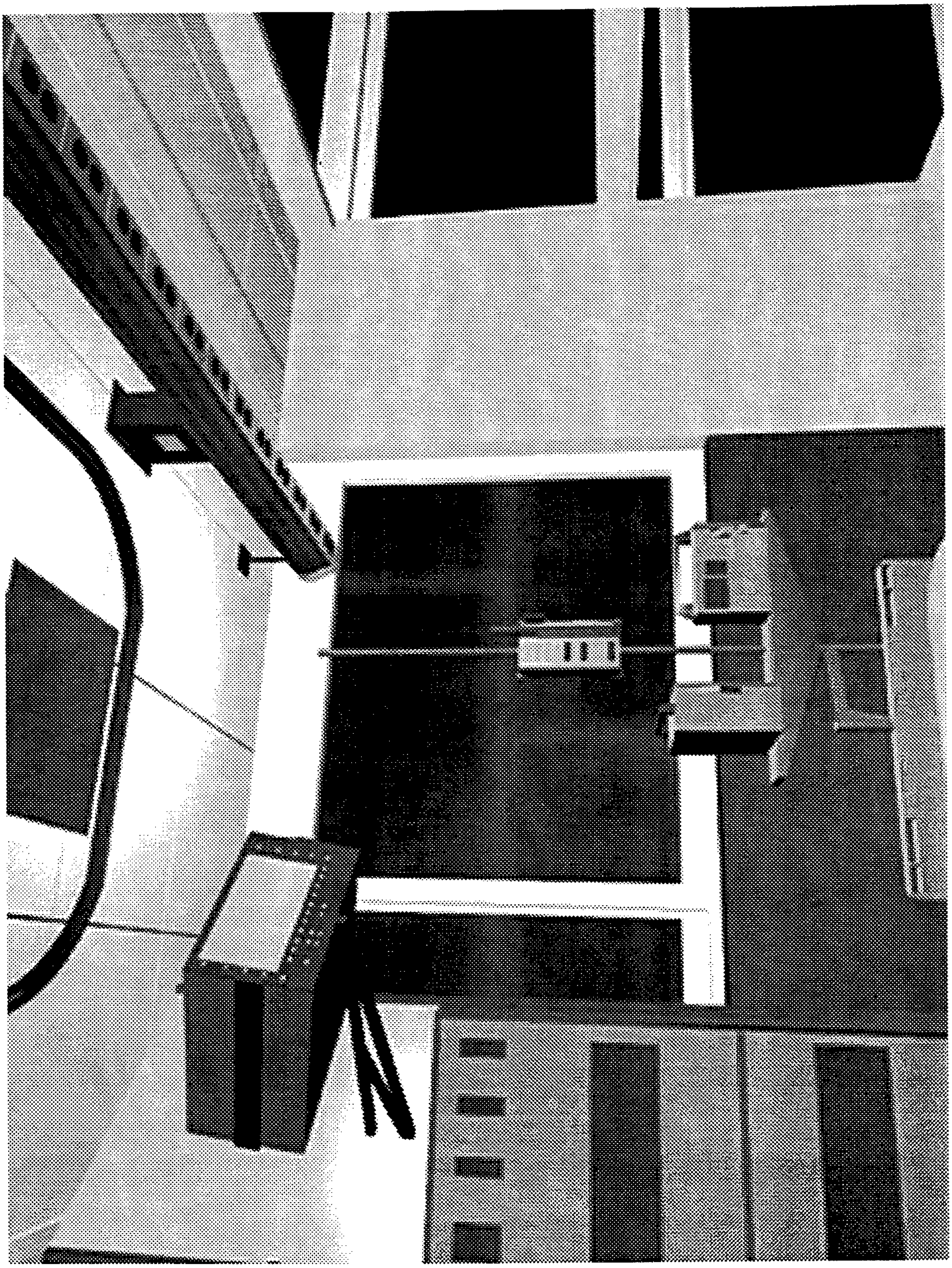


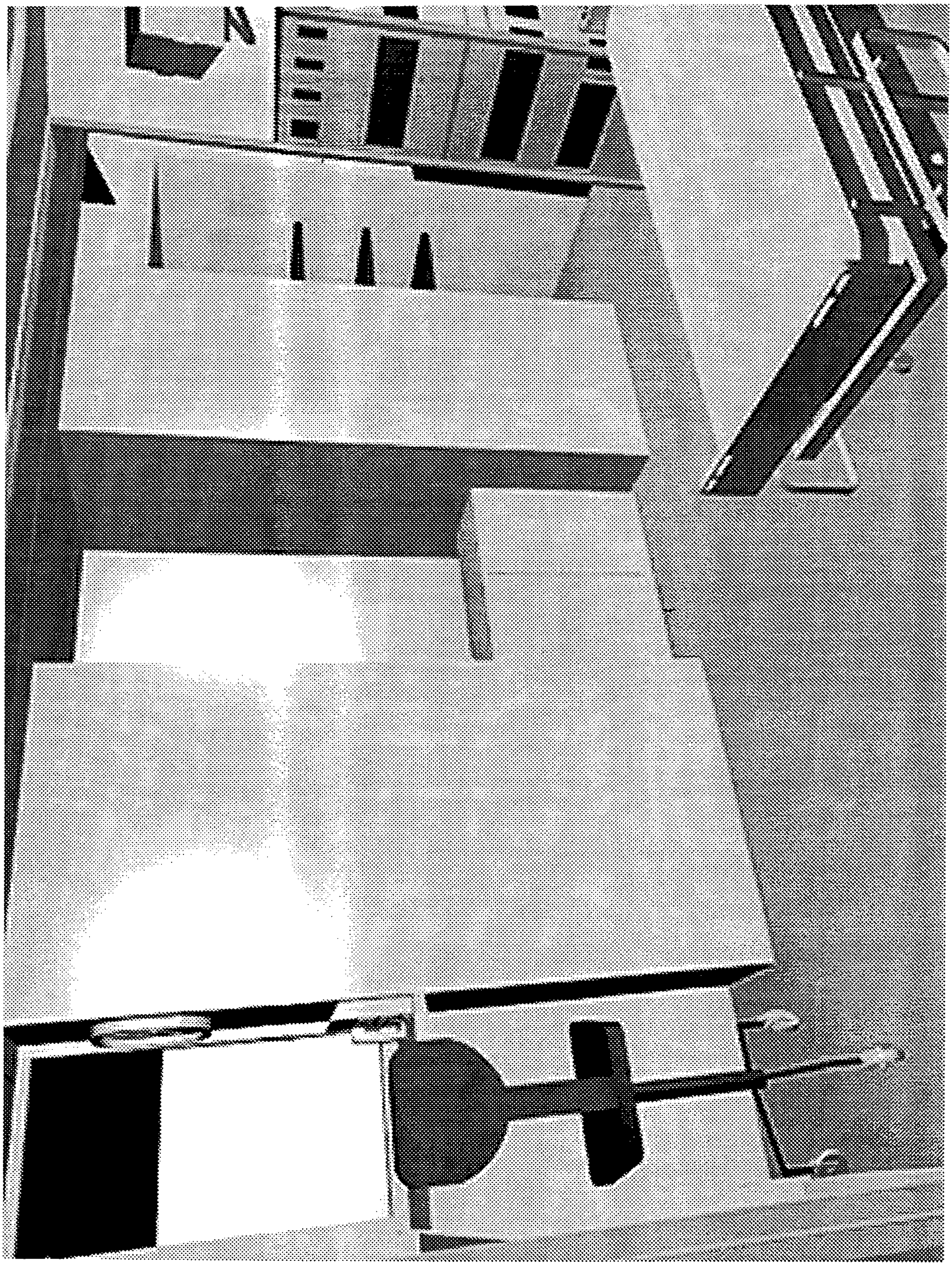


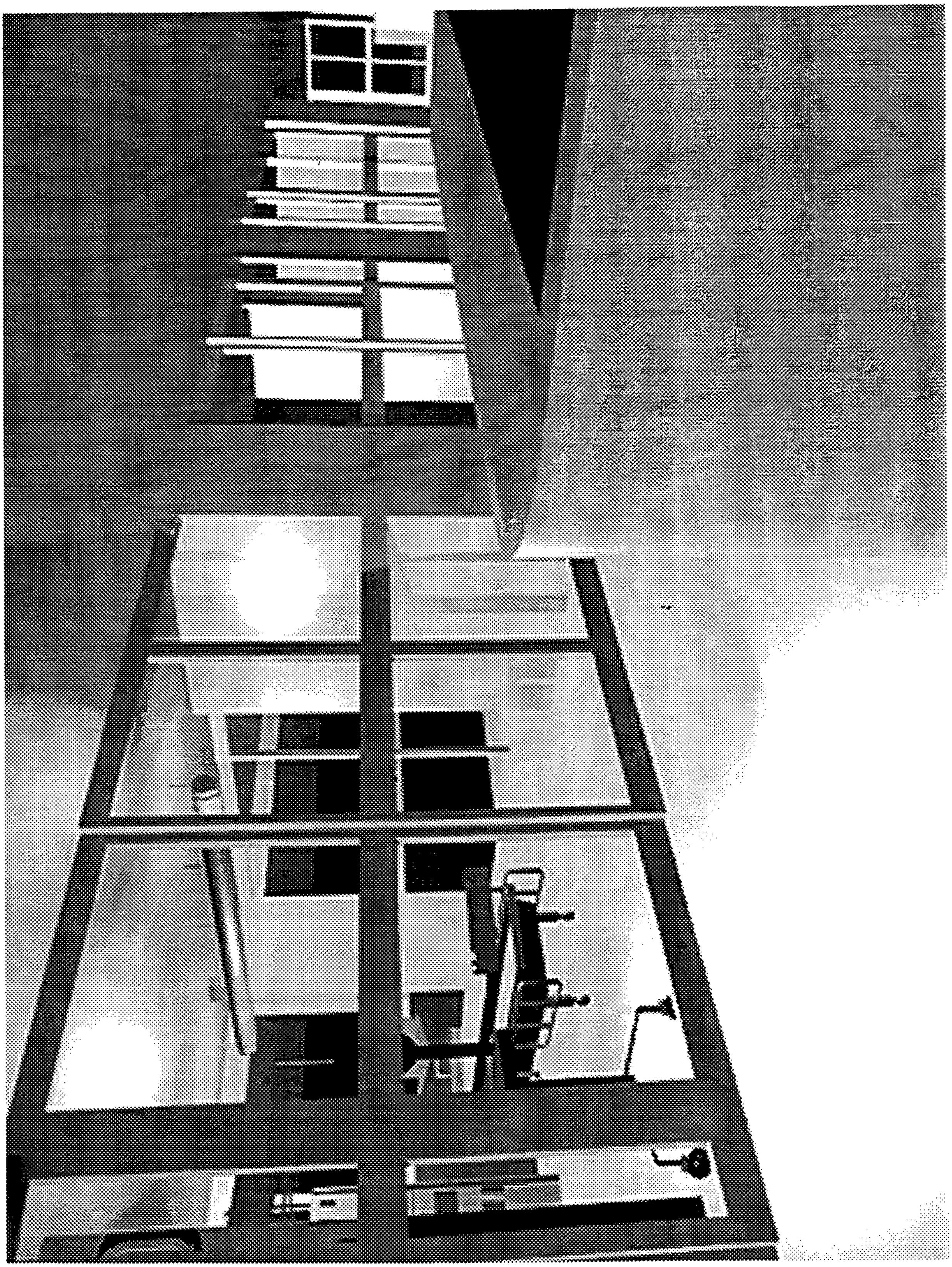


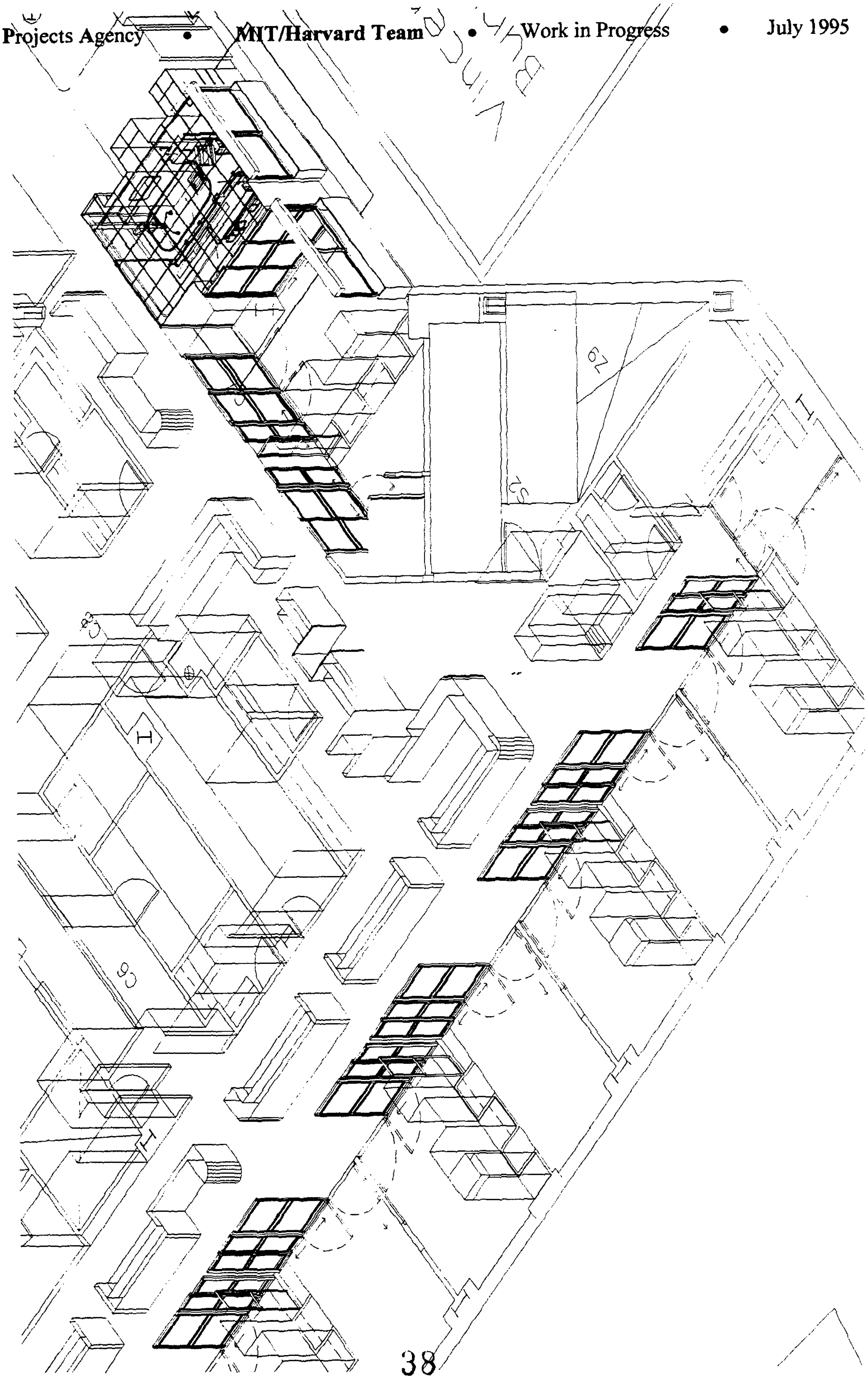


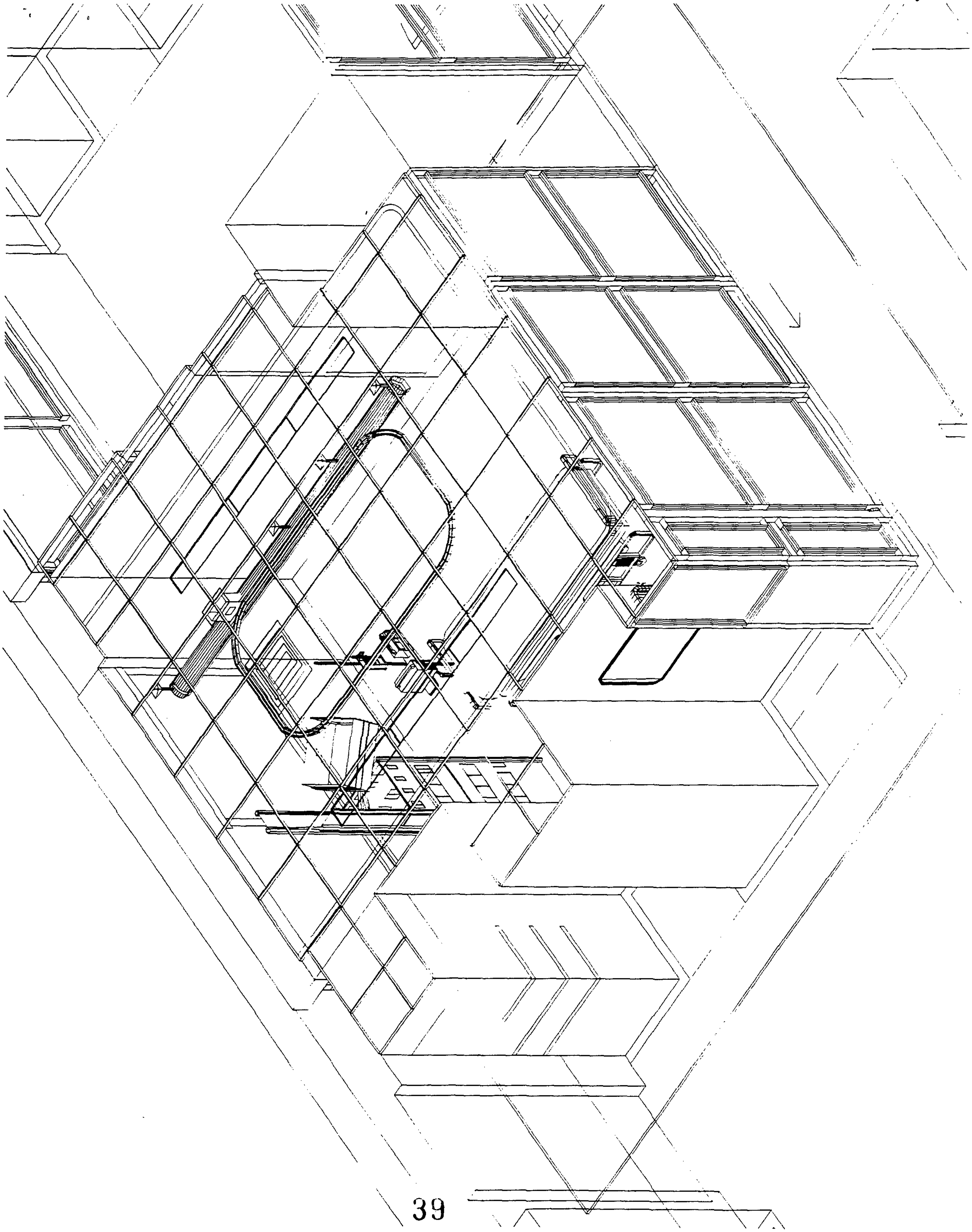


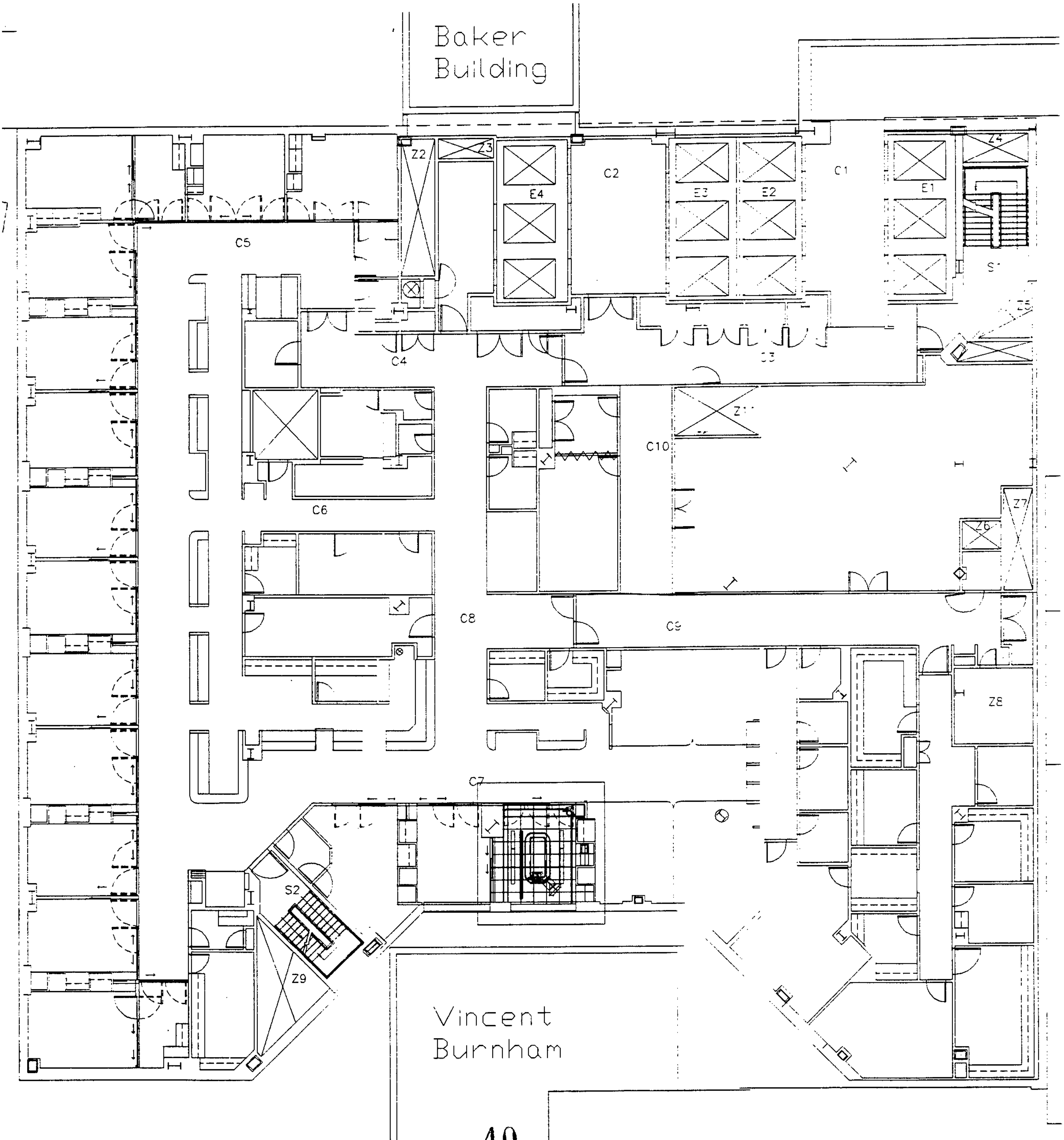


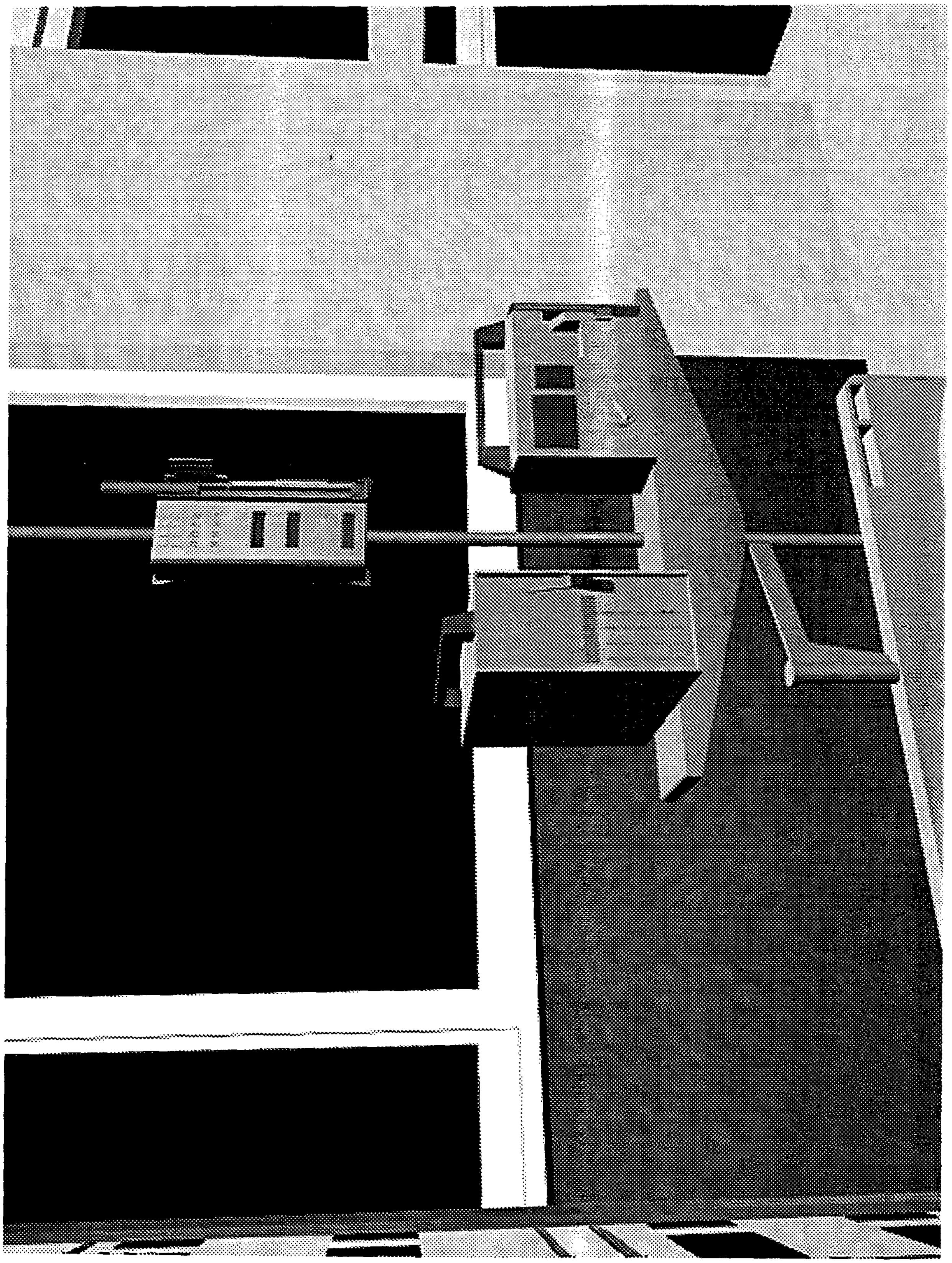


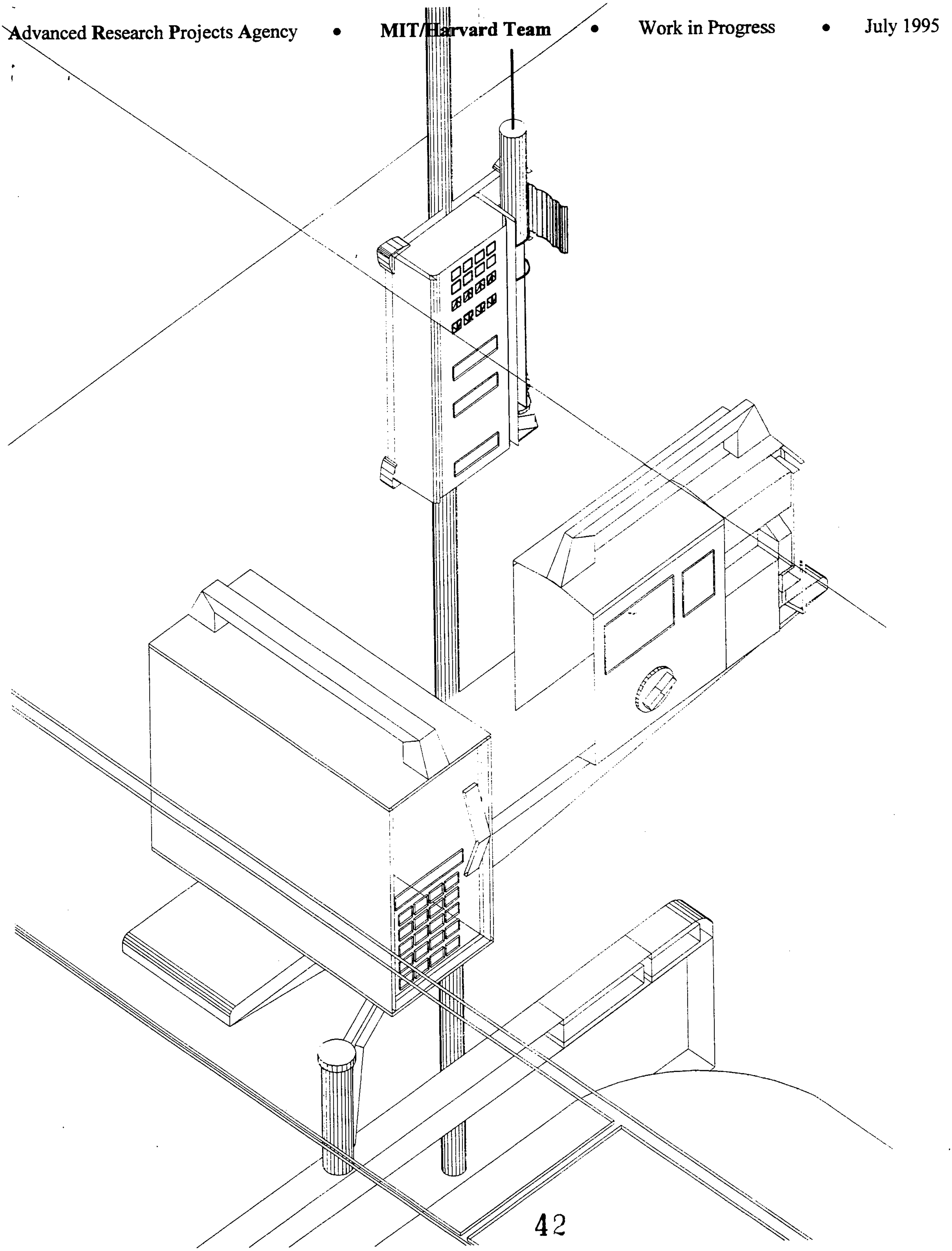


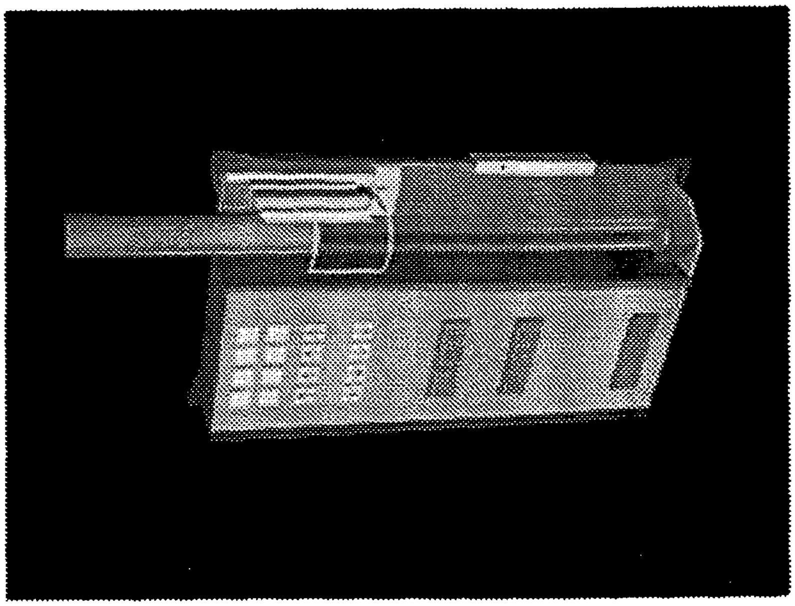


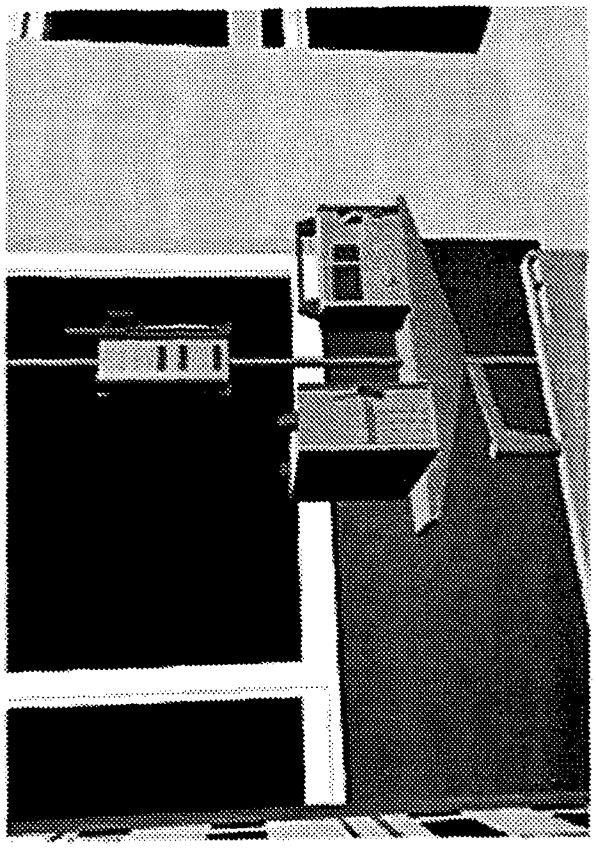


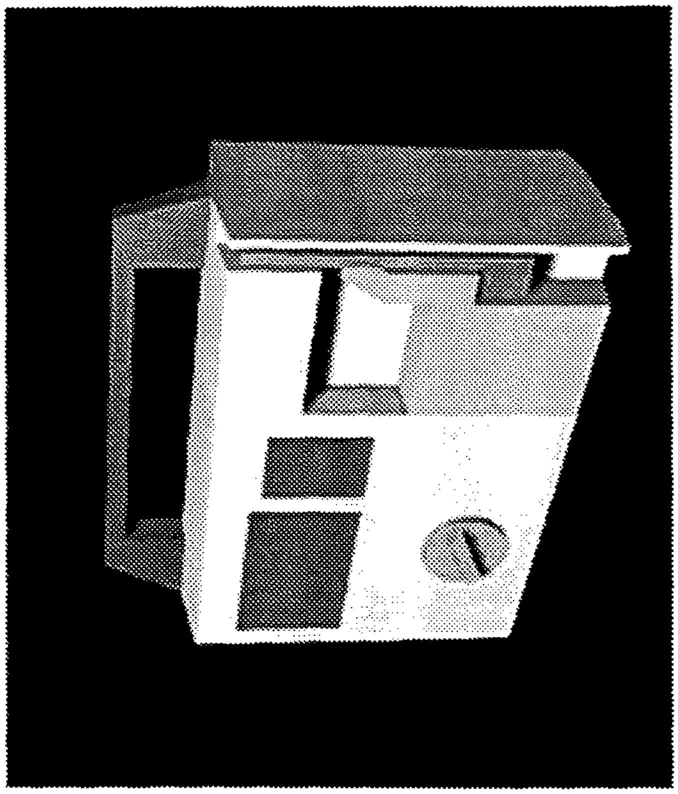

Baker Building
Z2
Z3
E4
C2
E3
E2
C1
E1
Z4
C5
C4
C3
C10
C6
Z7
Z6
C8
C9
Z8
C7
S2
Z9
Vincent Burnham

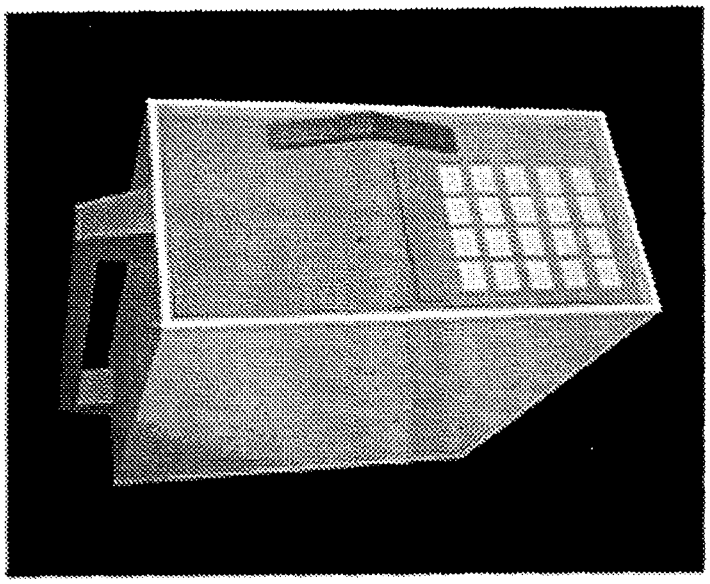


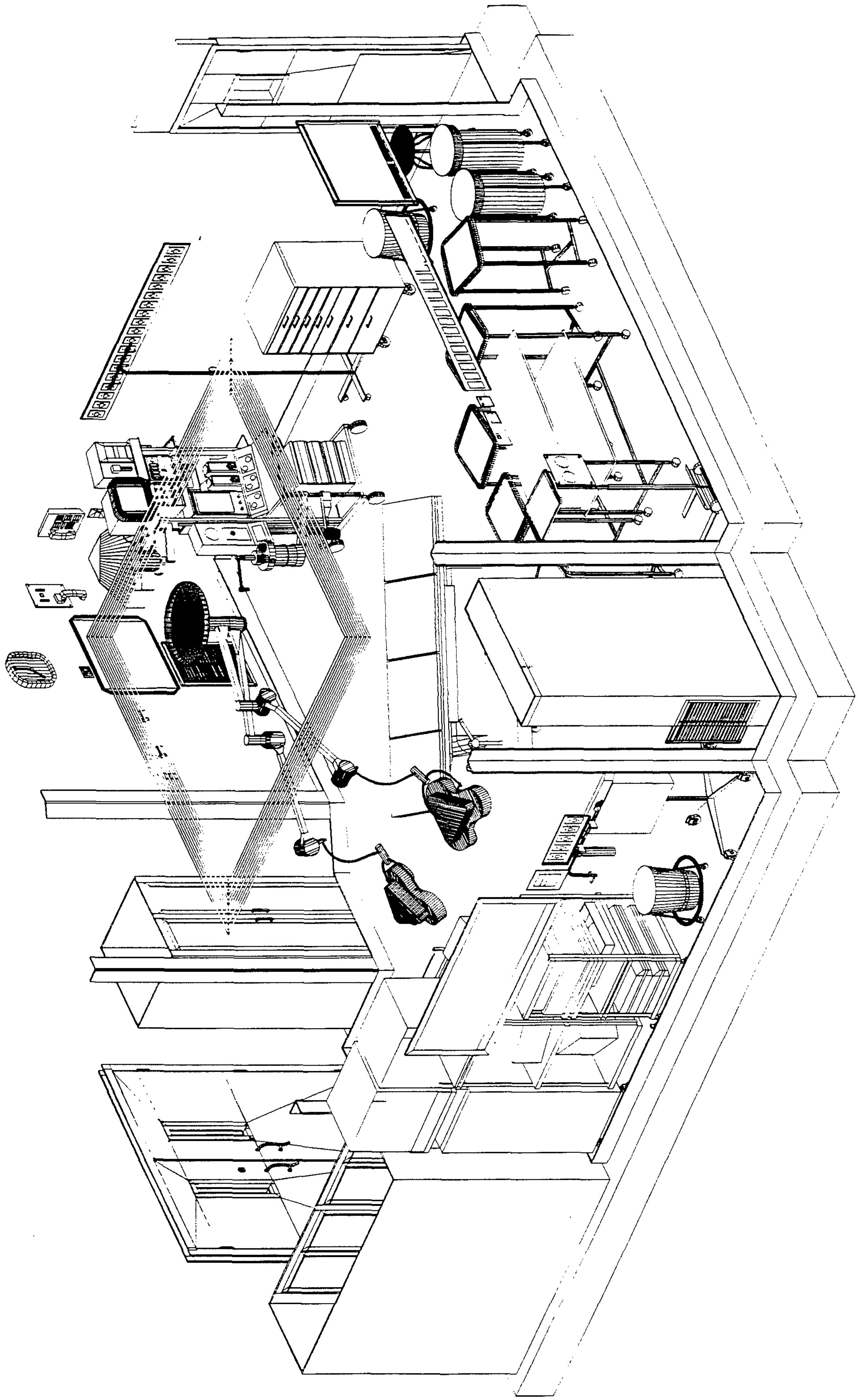


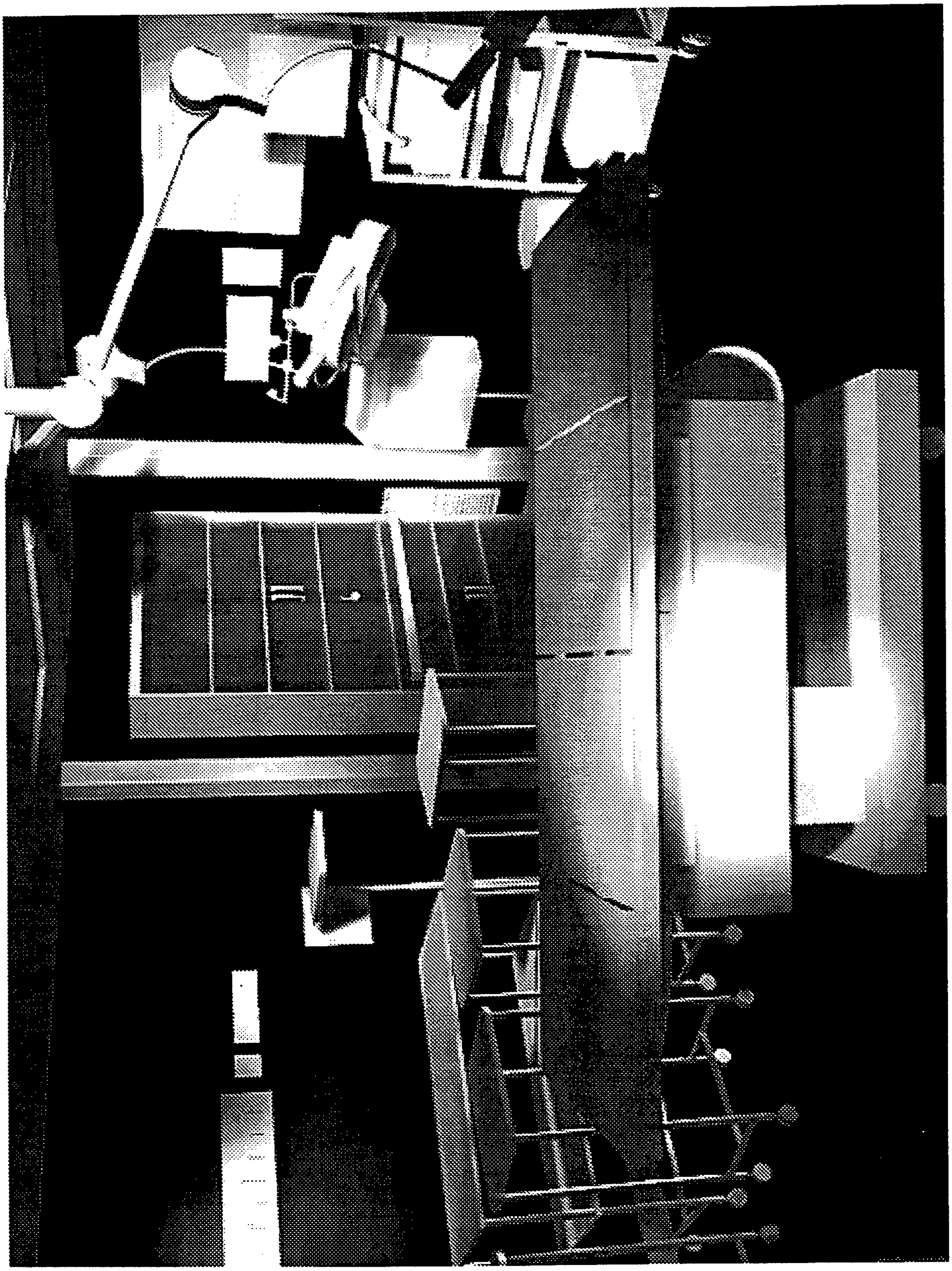


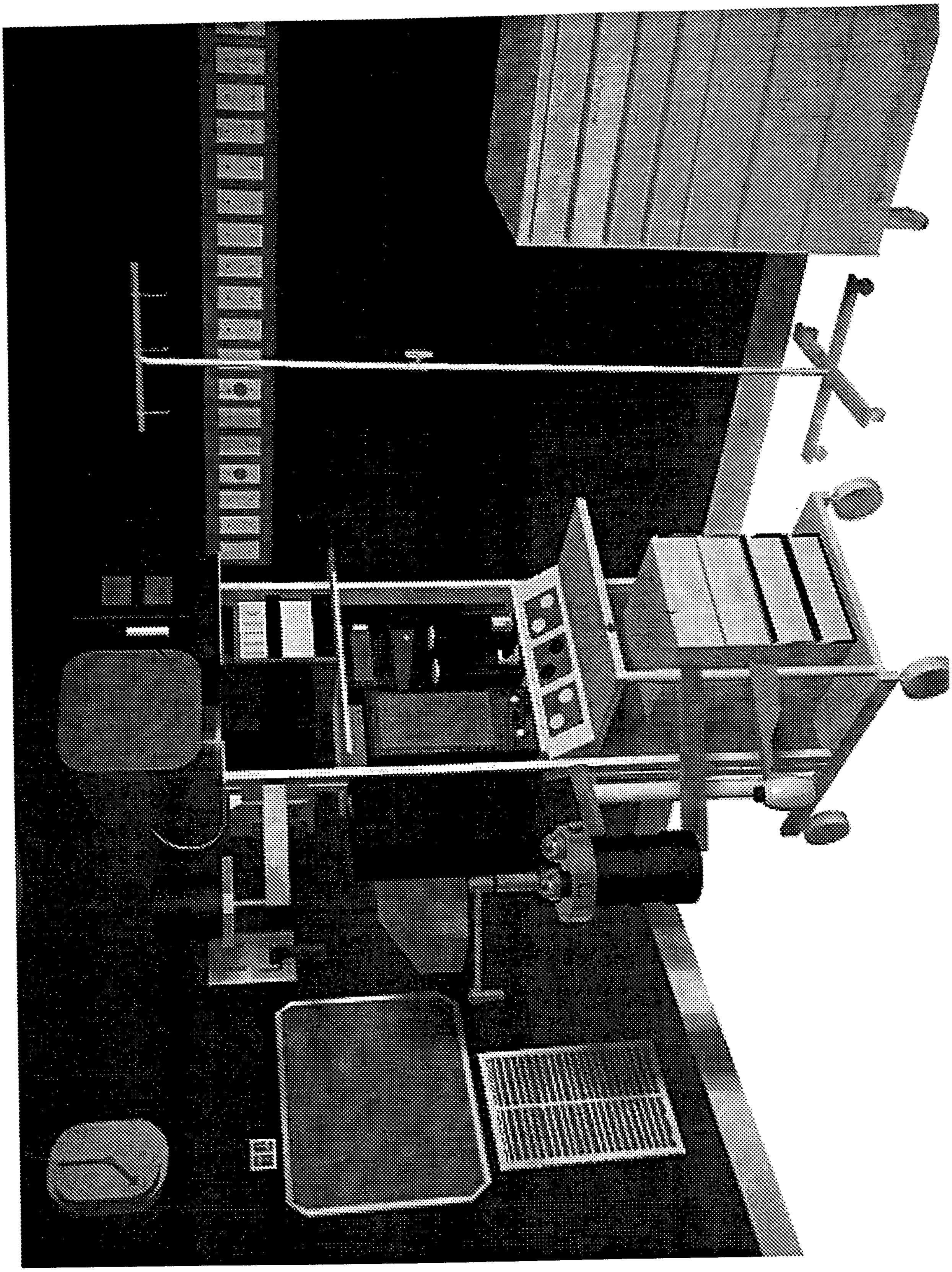


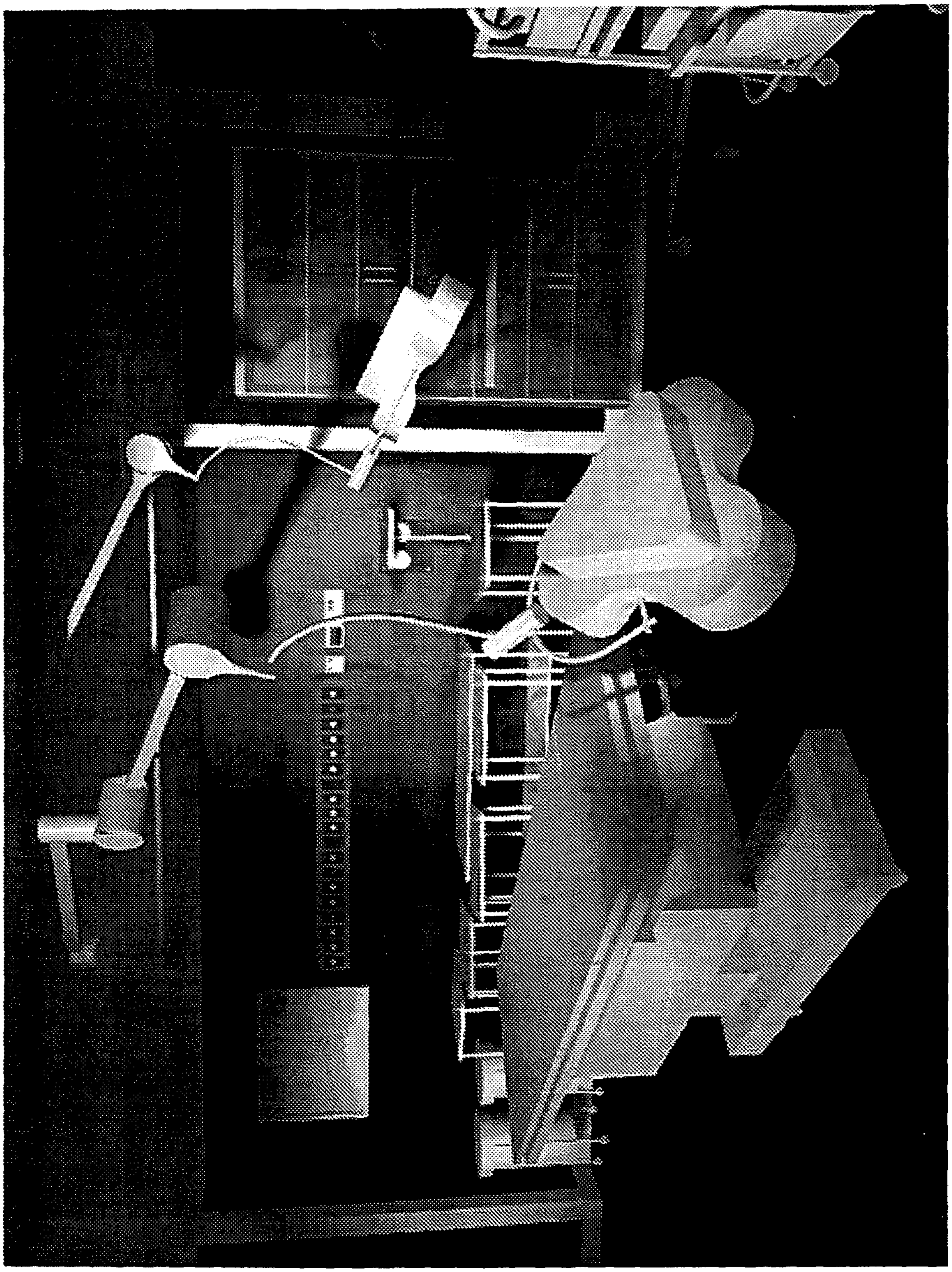


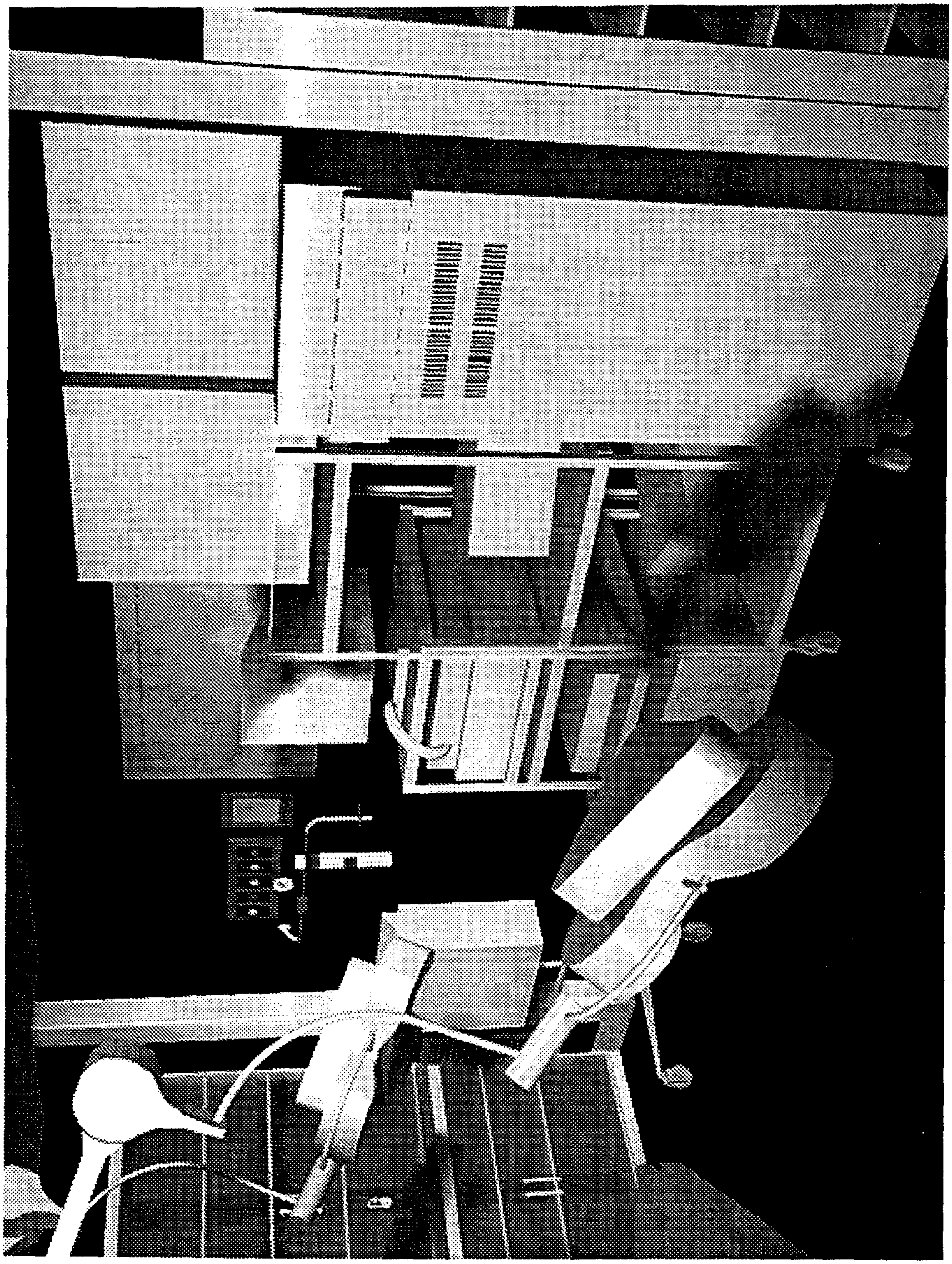


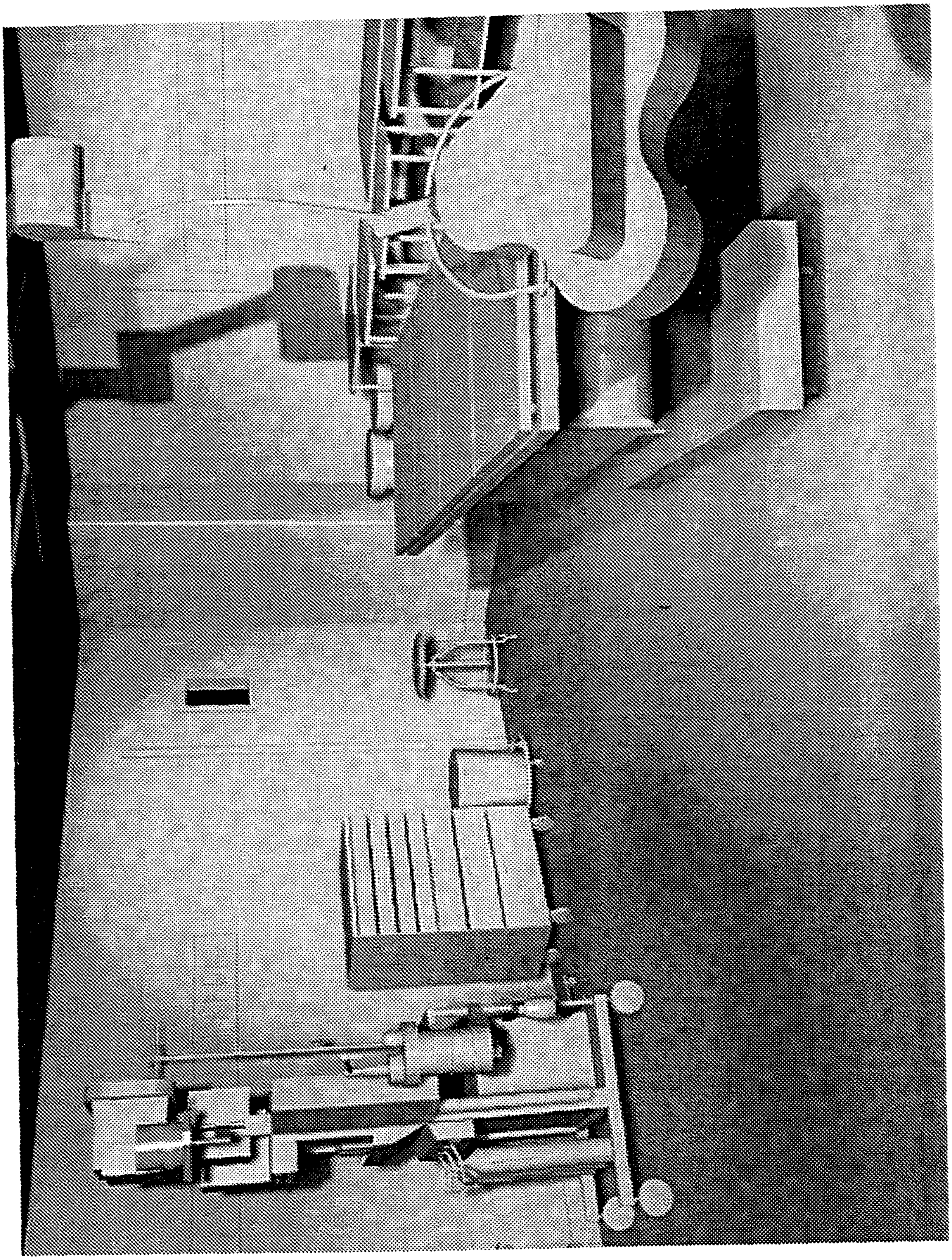










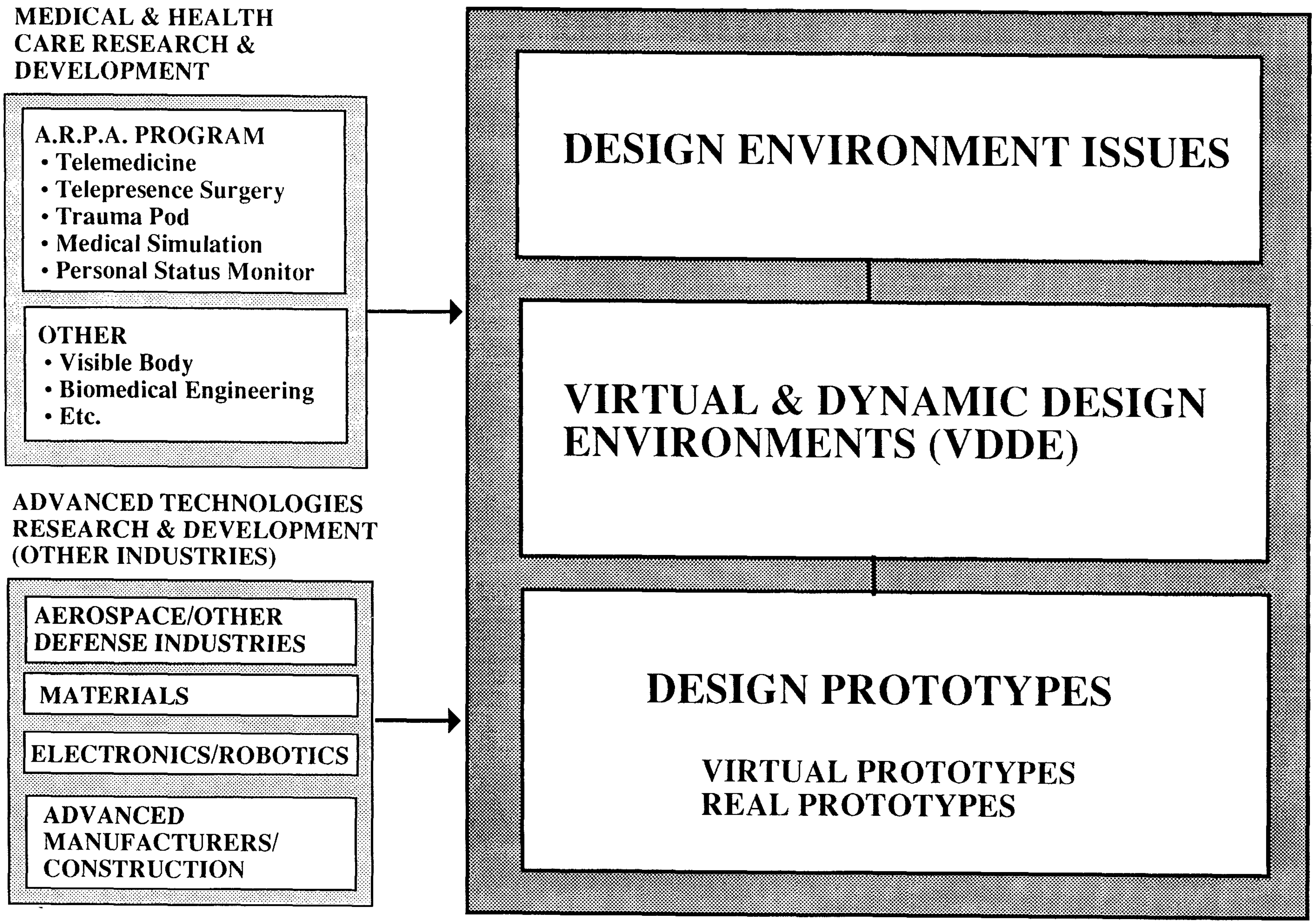


Appendix 5: Viewgraphs

1000 AD	1100 AD	1200 AD	1300 AD	1400 AD	1500 AD	1600 AD	1700 AD	1800 AD	1900 AD
1030 AD, monastery in Clumy - open ward system increased size of important rooms - houses for travellers and hospices for the poor, almonry, infirmary as "hospitality area"	1153 - Hotel Dieu of St. Jean in Augers	great hall as part of open ward system separate enclosures for plague patients 1293, Hopital Notre Dame des Fontenilles in Tonnerre	Medieval type churches with blocks of hospital wards around a chapel	1456, Ospedale Maggiore in Florence - cross ward as part of open ward system Nicolaus Cusa 1460 - weights and measures - scientific study	Bedlam (Bethlehem Hospital,) - development or private rooms Kirkbride System (American way of classifying patients) Julius Hospital 1576; ward and chapel config., medium-sized ward	Nicolaus Steno 1665 - anatomy of the brain US first settled in Jamestown, 1607 - original English medicine was in guilds: 1. physicians 2. surgeons 3. apothecaries 4. midwives 5. quacks	- Newton - Kepler - Hoffmann - life based on presence of universal fluids - G.E.Stahl - theory of the conscious soul - Edinburgh - diseases either asthemic (lack of stimulus) or sthenic (excessive stimulus) - Hahneman - homeopathy - studied symptoms, not causes of diseases) 1751 - founding of Pennsylvania Hospital in Philadelphia - central admin. block 1773 - founding of New York Hospital - cells for insane - European absolutism influences issue of well-being of citizens	1821 - founding of MGH - hospitals for variety of people 1890's - charity hospitals pavilion plan as organizing principle- Paris, Hotel Dieu 1861 - US adopted bed ideas from military barracks (simple remodelling not healthy) Johns Hopkins -844 morphine 1846 ether at MGH Lister 1866 Pasteur 1886 steam sterilization 1870's - hospitals for the poor (rich had private doctors)	1900's - privately funded hospitals Vanderbilt, Whitney, Rockefeller, Hopkins 1910, Goldwater, skyscraper plan for hospitals move toward private room hospitals

4000 BC	3000 BC	2000 BC	1000 BC	500 BC	250 BC	0	250 AD	500 AD	750 AD
Babylon - rising of fertility cults; priestly rituals of death and rebirth	- Imhotep ()2649-2150 BC, Egypt) priest of sun god Re at Heliopolis, officer of Zoser (2360 - 2611 BC), "medico-magical spells" as in Leiden Papyrus - spells for curing and causes illness - sick were bathed in sanctified water, spent nights in sanitorium - House of Life temple as house of medicine - Physician of the Eyes - Physician of the Belly - Shephard of the Anus - Chief of Dentists women healers: - Peseshet - Tame - cauterization - bleeding - circumcision - obsidian blades	Babylon - priests doing surgery on battle wounds issues of cleanliness, anesthesia, diet	- cremation of the dead replacing burial - priestly functions separated into religious/other such as medicine	- Hippocrates in Greece, 5th C BC- beginnings of scientific and ethical basis for science - Aulus Gellius - Alexandrian anatomy and physiology	Greek Askelpia as early hospita type- stoa Pergamon - Hall for Dreamers, latrine, temple, emperor's room stadium, treatment hall - Cato	- Galen (Roman doctor, 200 AD) founded study of anatomy, pathology, pharmacology, physiology - Roman military hospitals, Vindonissa- in fields, modified barracks - valetudinarium	- Oribasius (325-403 AD) - 310 AD: St. Basil opened hospit al at Caesarea 4th C - start of hospitals for lepers, etc. - run by tradesmen	- Paul of Aegina (625 - 696 AD) - 475 AD: Early Christian monastic hospices - Turmanin in Syria; inn for pilgrims 7 works of mercy: 1. food 2. drink 3. shelter 4. clothing 5. healing 6. jail? 7. bury dead 610 AD, Alexandria - 4 maternity hospitals	- St. Gall Monastery , Switzerland, 830 AD - Abbot Gozbert - housed medieval Christian hospital - distinction rich and poor - House of the Physicians

INTEGRATED ENVIRONMENTS LABORATORY



DESIGN ENVIRONMENT ISSUES

- Surgical Area
- Room Level
- Building Level
- Complexes

- Spatial Design
- Environmental Quality
  (Visual, Lighting, Thermal, Etc.)
- Equipment Design & Human Interactions
- Communication/Display Devices
  & Interactions

- Architectural/Engineering
- Costs
- Facility Management
  Life-cycles
  Maintenance

VIRTUAL AND DYNAMIC DESIGN TOOLS (VDDE)

- Integrative
- Immersive
- Interactive
- Multisensory
- Environmental Dynamic
  Motion & Temporality

- Multiple User Concept Design & Evaluation
- Distributed Design Simulations
- Anticipates Problems Prior to Construction
- Training Applications

- VDDE Technology Development
  Systems, Devices, Interfaces, Parallel Processing Applications
- Environmental Simulations
  (Visual, Lighting, Acoustical, Thermal)
- Equipment, Display Systems, Control Systems, Device Interactions

DESIGN PROTOTYPES:
MEDICAL & HEALTH CARE ENVIRONMENTS

- Systems Integration/Data Fusion
  Standards, Systems, Software, Displays
- Applications of New Materials
  Smart Materials, Composites
- Applications of Advanced Manufacturing Concepts
  Rapid Prototyping

- Virtual Prototypes
  Distributed
- Physical Mockups
  Full-Scale Rooms
- Prototype Installations
  MGH & Elsewhere

Advantages of a Virtual Reality System for Prototyping, Evaluation, and Testing

Prototyping

- ability to create and experience different ideas and possibilities based on a single constructed model
- time saving by virtue of possibility of "saving experiences" for later review and adjustment - only possible currently through human memory
- speed with which multiple options can be initiated and explored

Evaluation

- possibility of combining and splicing ideas in virtual environment without need to physically regenerate composite ideas
- possibility to review and evaluate multiple schemes rapidly, makes changes, and save revised versions
- inherent flexiblity of virtual prototype in its ability to be transformed and manipulated by multiple users over a period of time

Testing

- cost saving of testing ideas and schemes in virtual world
- concept of shared experience in virtual space
- allowing audience to experience idea or schema without expending the time or money necessary to physically build individual ideas

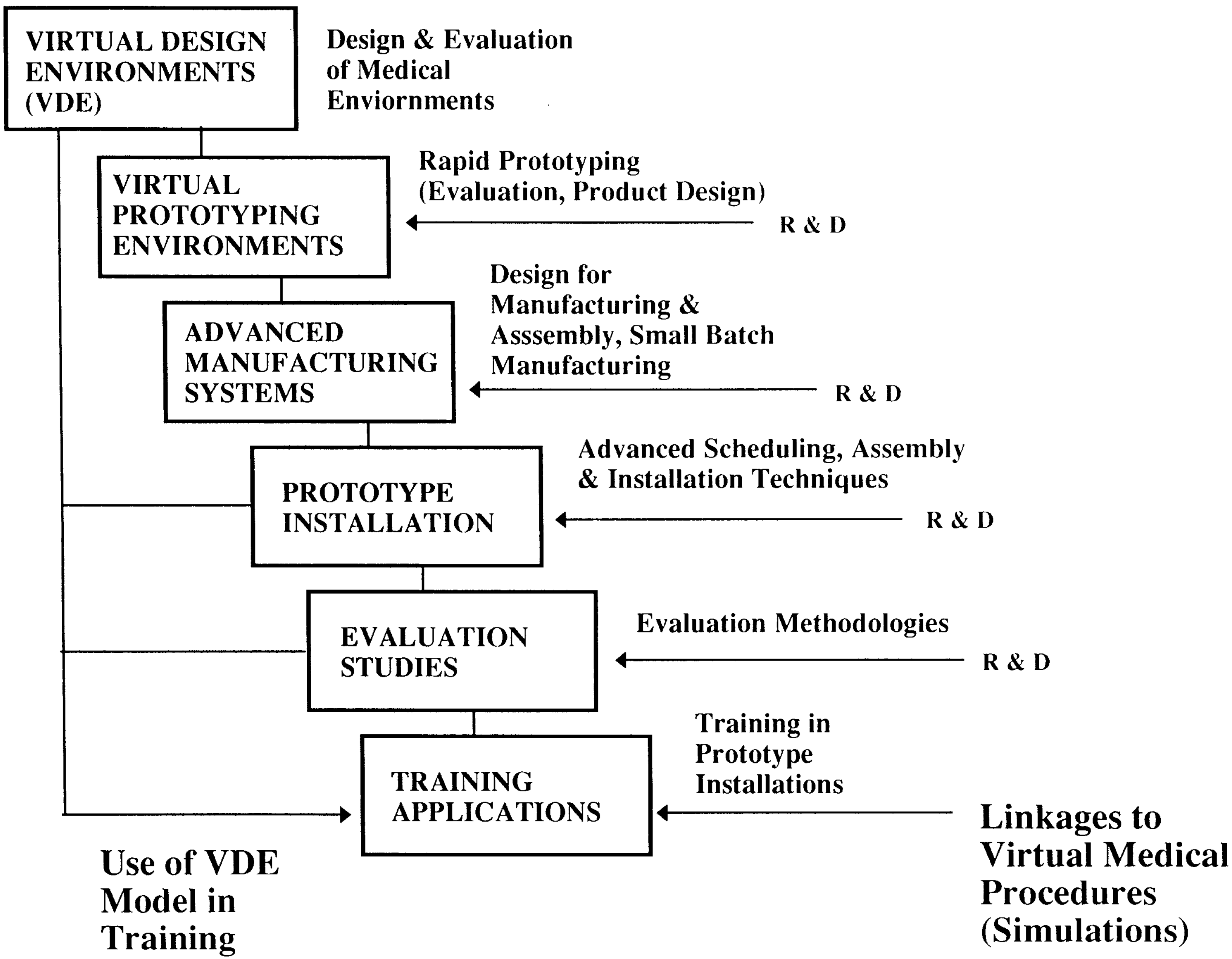
Surgical Room of the Future Project Participants

ACADEMIC REALM:
- university professors
- architecture graduate students
- engineering graduate students
- university administrators

COMMERCIAL REALM:
- business executives
- accountants
- marketing strategists
- hospital administrators

MEDICAL REALM:
- radiologists
- general surgeons
- laparoscopic surgeons
- anesthesiologists
- nursing staff
- technical support crews

ARCHITECTURE AND ENGINEERING REALM:
- project architects
- software engineers
- civil engineers
- aerospace engineers
- material scientists
- product developers



VIRTUAL DESIGN ENVIRONMENTS (VDE)
Design & Evaluation of Medical Enviornments
VIRTUAL PROTOTYPING ENVIRONMENTS
Rapid Prototyping (Evaluation, Product Design)
R & D
ADVANCED MANUFACTURING SYSTEMS
Design for Manufacturing & Asssembly, Small Batch Manufacturing
R & D
PROTOTYPE INSTALLATION
Advanced Scheduling, Assembly & Installation Techniques
R & D
EVALUATION STUDIES
Evaluation Methodologies
R & D
TRAINING APPLICATIONS
Training in Prototype Installations
Linkages to Virtual Medical Procedures (Simulations)
Use of VDE Model in Training

Traditional modes of communication for designers

Media - drafted inked drawings - generated individually
- pencil or color renderings - generated individually
- 3-dimensional models -generated individually

Interaction - meetings/presentations
- telephone calls
- occasional site visits

Surgical Room of the Future

Future modes of communication for designers

Media - computer-aided drawings - multiple drawings generated from one model
- digitally-enhanced images - generated indivually
- 4- and 5-dimensional models - infinite variances generated from model

Interaction - combination of live meetings with video teleconferencing
- on-line dialoguing and image transference
- site visits with animated visualizations

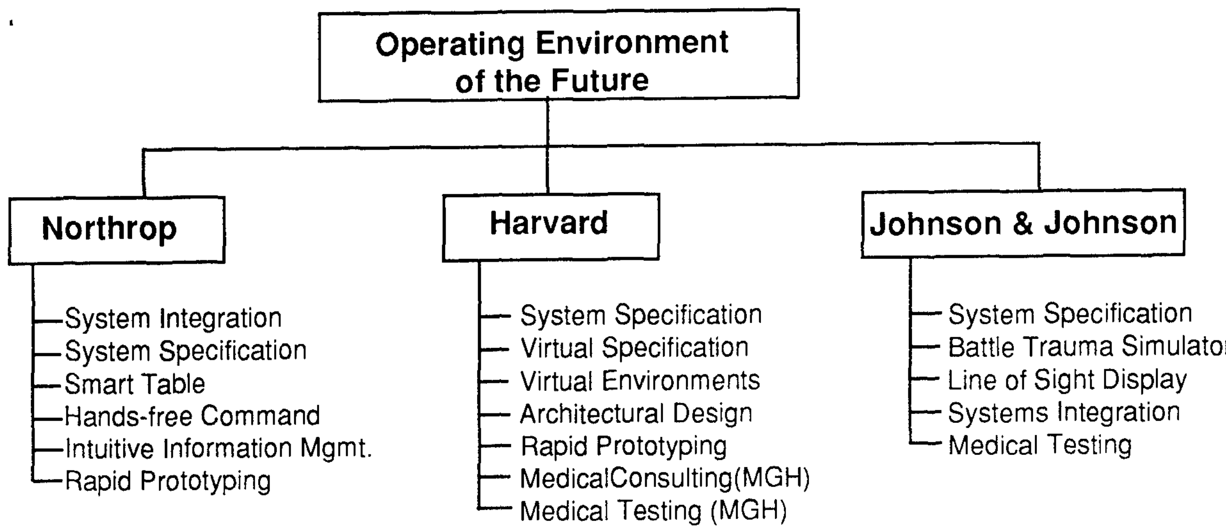


Figure 6-1. Operating Environment of the Future Consortium

Advantages of the Internet as a Design Tool

Cost Efficiency	Total cost of most Internet applications is a low yearly fee, with the possiblilty of local phone chages for non-university affiliates.
Rapid Communication and Exchange of Ideas	The rate of information flow over the Internet depends on factors such as time of day, number of users on the system, and system maintenance, but lag is generally not more than a few seconds.
Direct communication versus "posting"	The Internet affords the possiblilty of realtime on-line dialoguing, as well as "posting" ideas, or leaving messages, for others to see and respond to at their leisure.
Multiple-party and private conferencing	Unlike any standard conference call, Internet applications such as the IRC allow for multi-user conference calls while simultaneously offering the possiblility for private "talking," all in the same conversation.
Possibility of multi-media transference	While text transference is currently the easist and fastest type of information flow over the Interent, within the next several years there will be options available to tranmsit sounds and images as well, both for display and manipulation.
Rapid access to resources	The research applications of the Internet are one of its strongest features; convenient access to library and information systems the world over is readliy available and easily searchable.

VISUALIZATION
A. Geometric Models
   1. wire frame
   2. surface
   3. solid
B. Dynamic Interaction Capabilities
   1. object movement
      a) object translation
      b) object rotation
      c) kinematic behavior
   2. object (physical property) modification
      a) configuration
      b) size
      c) texture
      d) color
      e) weight, density
C. Simulation Modeling Capabilities
   1. physical behavior
      a) natural (dropping, falling, etc.)
      b) external controlled, software controlled, teleoperation
         1) direct visual control
         2) video/camera
         3) virtual model
      c) response controlled, sensor controlled (smart skins)
   2. technical performance
      a) structural
      b) thermal
      c) vibration
      d) electro magnetic
D. Model Development and Manipulation
E. Rendering and Shadowing
   1. ray tracing
   2. radiosity
F. Animation

COMMUNICATION/ANNOTATION
A. Tracking Design Decisions/Potential Retrieval
B. Multi-user Control and Interaction: Shared Space
C. Communication (real-time) among participants
D. Communication to near and remote areas - network, e-mail, fax, etc.
E. Monitoring Participant Interaction (instant replay)
F. Recording/Live reproduction Capcbility (video/audio)

TACTILE/FORCE FEEDBACK
A. Force Feedback (larger movements)
B. Texture, Feeling
C. Temperature, Humidity, etc.
D. Data Glove, Haptic Interface Devices
E. Audio Analog for Haptic Modeling

INFORMATION/DATA REALIZATION
A. Regnet - high-speed computing network

ACOUSTIC/SOUND ENVIRONMENT
A. Three-dimensional World Sound Design; Dynamic Interaction
B. Acoustic Three-Dimensional Modeling; based on radiosity modeling
C. Orientation Beacon
D. Environmental Relaxation (music)
E. Acoustic Simulation
F. Real-time Phase-Related Sound Damping

LIGHTING
A. Modify and Alter Contrast
B. Relation to Object Control
   1. voice
   2. knee switch, toe pedal, etc.

THERMAL/AIR MOVEMENT
A. Temperature Distribution
B. Air Flow Within Room
   1. ventilation
   2. general air flow
C. Dispersal of "Pollutants"
   1. elimination of toxins and pollutants of room with smart materials and skins
   2. infection control of people and equipment
D. Fluid Flow

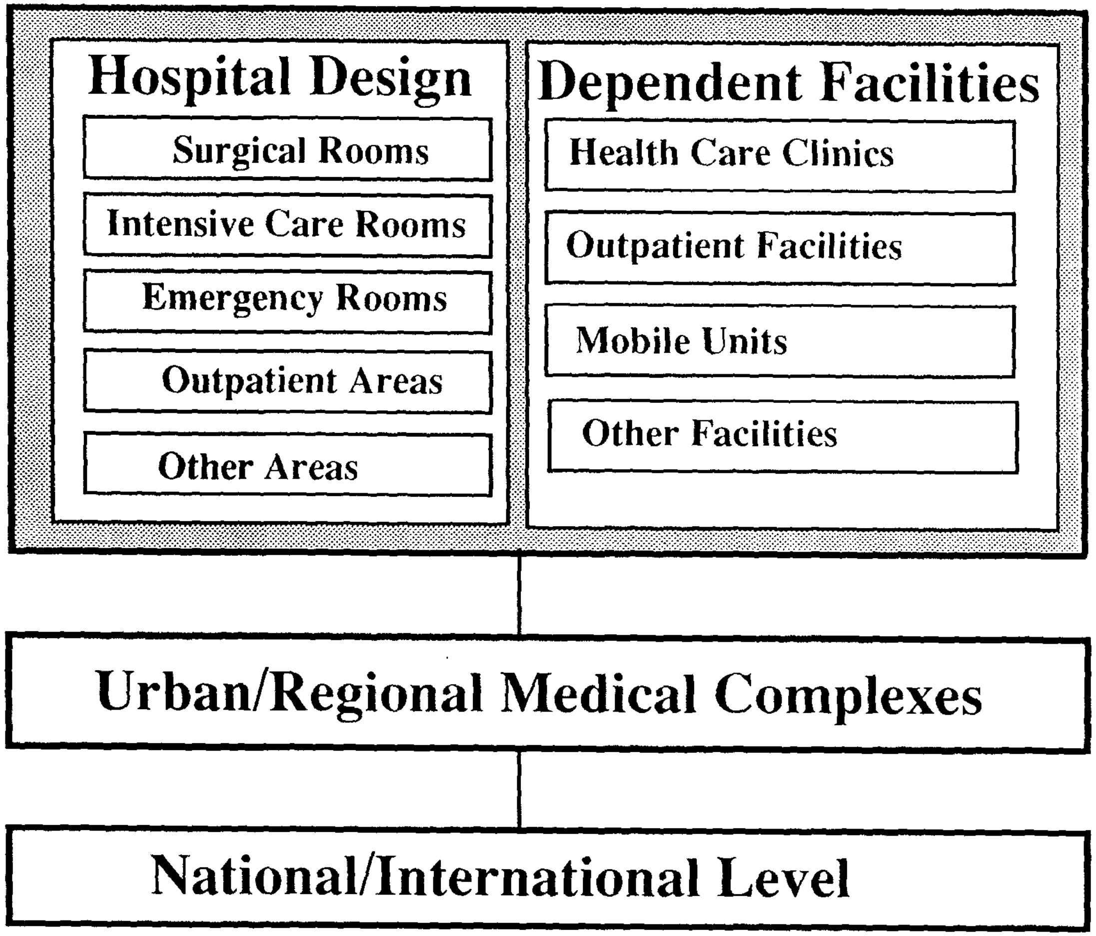
OBJECT RECOGNITION
A. Voice Control
B. Gesture Control

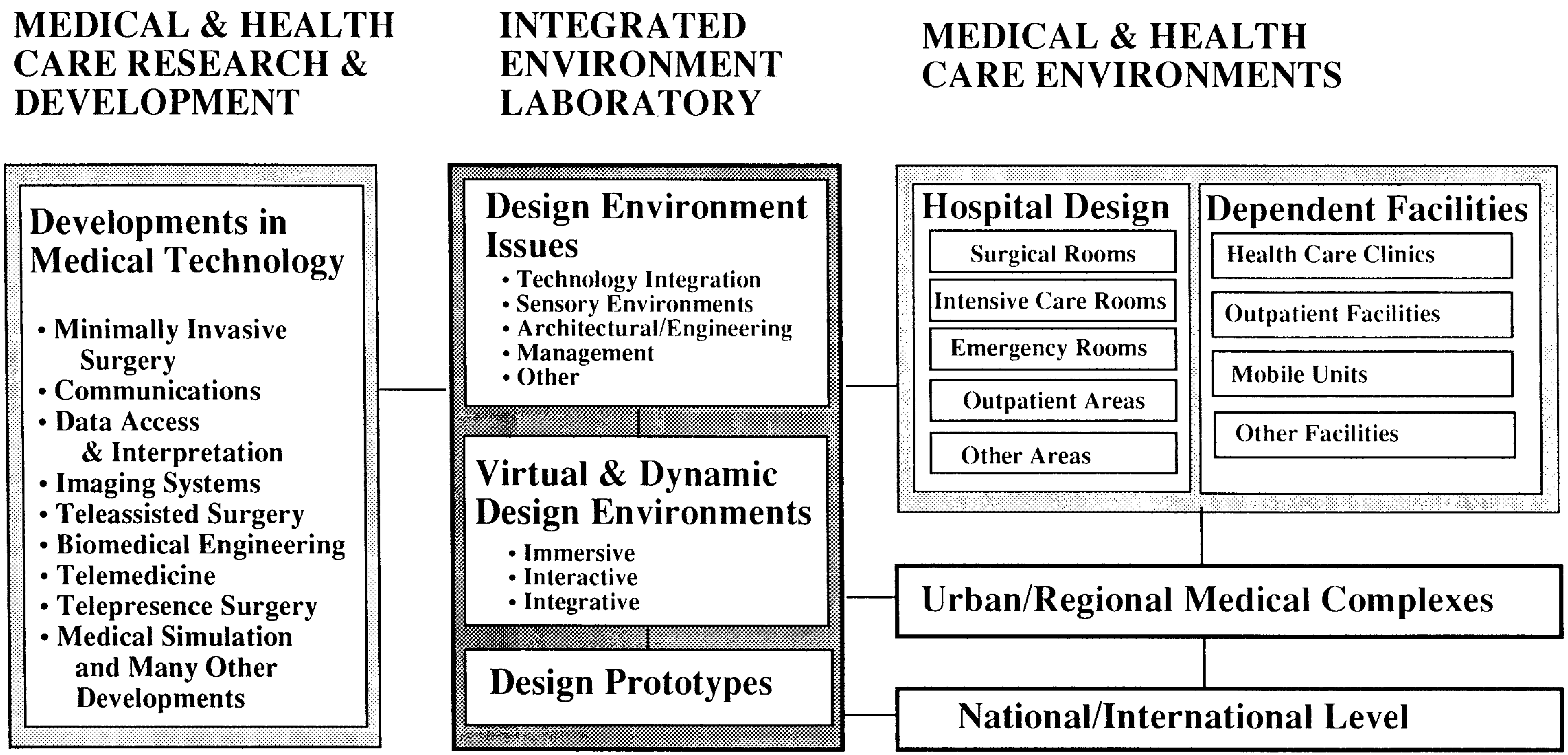
DISPLAY/INTERACTIVE TECHNOLOGY
A. Helmets
B. Data Glove
C. Heads-up Technology

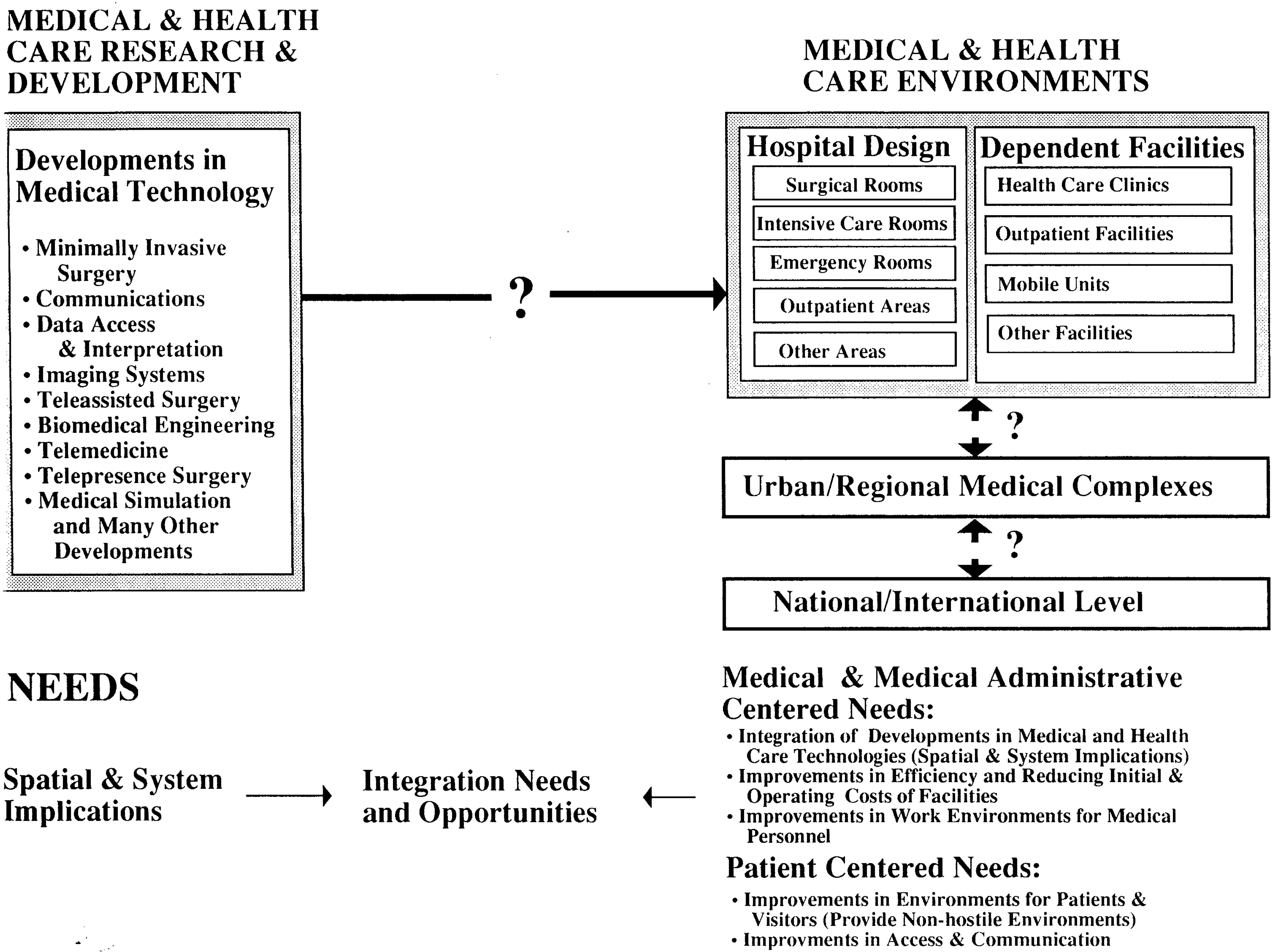
NETWORK
A. Information, Menus, Libraries
B. CD-ROM
C. Live Teleconsulting

INTERFACES
A. Hardware
B. Software

MEDICAL & HEALTH CARE ENVIRONMENTS




MEDICAL & HEALTH CARE RESEARCH & DEVELOPMENT
Developments in Medical Technology
• Minimally Invasive Surgery
• Communications
• Data Access & Interpretation
• Imaging Systems
• Teleassisted Surgery
• Biomedical Engineering
• Telemedicine
• Telepresence Surgery
• Medical Simulation and Many Other Developments
INTEGRATED ENVIRONMENT LABORATORY
Design Environment Issues
• Technology Integration
• Sensory Environments
• Architectural/Engineering
• Management
• Other
Virtual & Dynamic Design Environments
• Immersive
• Interactive
• Integrative
Design Prototypes
MEDICAL & HEALTH CARE ENVIRONMENTS
Hospital Design
Surgical Rooms
Intensive Care Rooms
Emergency Rooms
Outpatient Areas
Other Areas
Dependent Facilities
Health Care Clinics
Outpatient Facilities
Mobile Units
Other Facilities
Urban/Regional Medical Complexes
National/International Level


MEDICAL & HEALTH CARE RESEARCH & DEVELOPMENT
Developments in Medical Technology
• Minimally Invasive Surgery
• Communications
• Data Access & Interpretation
• Imaging Systems
• Teleassisted Surgery
• Biomedical Engineering
• Telemedicine
• Telepresence Surgery
• Medical Simulation and Many Other Developments
?
MEDICAL & HEALTH CARE ENVIRONMENTS
Hospital Design
Surgical Rooms
Intensive Care Rooms
Emergency Rooms
Outpatient Areas
Other Areas
Dependent Facilities
Health Care Clinics
Outpatient Facilities
Mobile Units
Other Facilities
?
Urban/Regional Medical Complexes
?
National/International Level
NEEDS
Spatial & System Implications
Integration Needs and Opportunities
Medical & Medical Administrative Centered Needs:
• Integration of Developments in Medical and Health Care Technologies (Spatial & System Implications)
• Improvements in Efficiency and Reducing Initial & Operating Costs of Facilities
• Improvements in Work Environments for Medical Personnel
Patient Centered Needs:
• Improvements in Environments for Patients & Visitors (Provide Non-hostile Environments)
• Improvments in Access & Communication